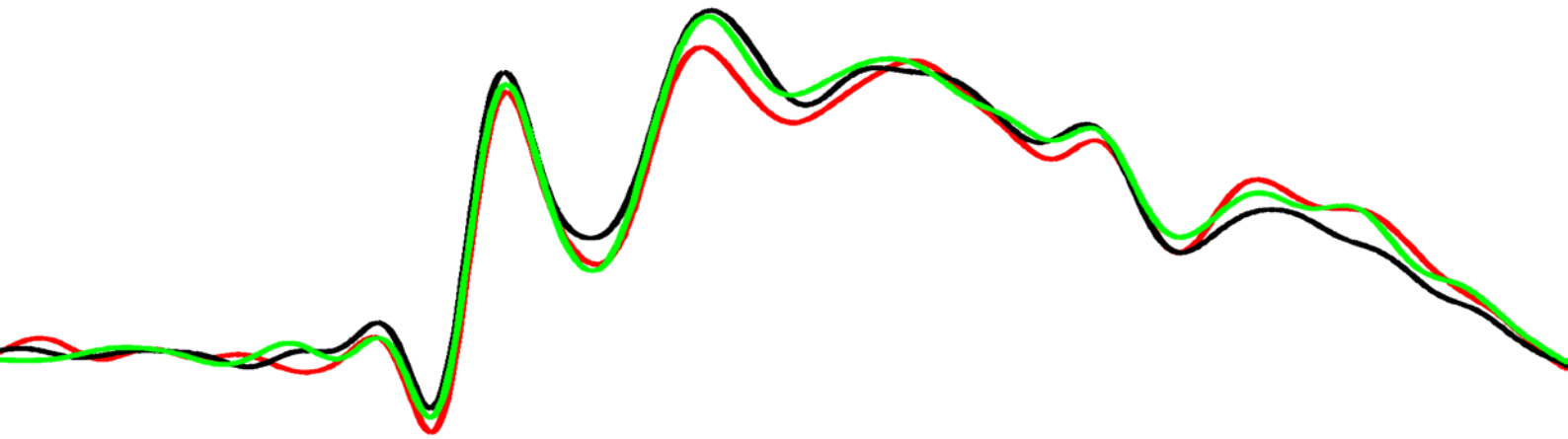
UNIVERSIDAD AUTONOMA DE MADRID

Facultad de Psicología

EXOGENOUS AND ENDOGENOUS ATTENTION TO EMOTIONAL STIMULI: BEHAVIORAL AND ELECTROPHYSIOLOGICAL CORRELATES



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PhD Thesis supervised by

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ATENCIÓN EXÓGENA Y ENDÓGENA

A ESTÍMULOS EMOCIONALES:

CORRELATOS CONDUCTUALES Y ELECTROFISIOLÓGICOS

Dominique Kessel

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Tesis doctoral dirigida por

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Meinen Eltern, Dorothee und Fred

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ABSTRACT

Previous data indicate that emotional stimuli are prioritized during both endogenous and exogenous attention. However, this evidence was obtained from studies exploring each of the two attentional modalities separately, and further proof is needed of this advantage when both attentional systems are simultaneously dealing with emotional events. Thus, the present Thesis explored this issue through behavioral and electrophysiological measures. The main purposes, always regarding emotional stimulation, were i) to explore how the endogenous-exogenous competition is resolved at the behavioral level and whether there is any advantage of one system over the other; ii) to disentangle the neural time course of these concurrent attentional processes, discovering if they are reflected in the event-related potential (ERP) in a parallel manner or in a serial order; iii) to analyze how stimulus valence and arousal modulate competing endogenous and exogenous attention. To that aim, two experiments employing concurrent but distinct target-distracter tasks were carried out. In Experiment 1, the task was fully randomized, while, in Experiment 2, emotional target conditions were presented in blocks, in order to facilitate the generation of affective contexts that resemble what occurs in real situations, in which endogenous attention is often directed towards long-lasting events. In the two experiments, both distracters (potentially capturing exogenous attention) and targets (to which endogenous attention was directed) were emotionally negative, neutral, and positive pictures. Behavioral results showed sensitivity to the emotional content of targets rather than of distracters. At the neural level, ERPs indicated an affective modulation in both attention modalities with no clear advantage of any of them. These ERP effects were reflected in a serial manner, and the effects did not show any significant endogenous-exogenous interactions, in favor of a certain functional segregation of both attentional systems in response to emotional stimuli. These effects were potentiated when a context was generated through blocked presentation of emotional targets. No advantage of the valence or arousal dimensions of pictures was observed.

RESUMEN

Datos anteriores indican que los estímulos emocionales se ven priorizados durante la atención endógena y exógena. Sin embargo, esta evidencia fue obtenida explorando cada modalidad atencional por separado, por lo que resulta necesario aportar datos adicionales que muestren esta ventaja cuando ambos sistemas atencionales procesan eventos emocionales de forma simultánea. La presente Tesis trata esta cuestión a través de medidas conductuales y electrofisiológicas. Los objetivos principales, siempre respecto a la estimulación emocional, fueron i) explorar cómo la competición entre endógena y exógena es resuelta a nivel conductual y si existe una ventaja de un sistema sobre el otro; ii) describir el curso temporal de estos procesos atencionales concurrentes, descubriendo si están reflejados en el potencial evento-relacionado (PER) de manera paralela o serial; iii) analizar cómo la valencia y el arousal de los estímulos modulan la atención endógena y exógena cuando están competiendo. Para ello, se llevaron a cabo dos experimentos que emplearon tareas de estímulos objetivo y distractor concurrentes pero distintos. En el Experimento 1, la tarea fue completamente aleatorizada, mientras que, en el Experimento 2, las condiciones del estímulo objetivo emocional fueron presentadas en bloque, con el objetivo de facilitar la creación de un contexto afectivo que imita lo que ocurre en situaciones reales en las que la atención endógena muchas veces es dirigida hacia eventos duraderos. En ambos experimentos, distractores (los cuales potencialmente capturaban la atención exógena) y objetivos (hacia los que iba dirigida la atención endógena) fueron fotos emocionalmente negativas, neutras y positivas. Los resultados conductuales mostraron una sensibilidad al contenido de los objetivos pero no de los distractores. A nivel neural, los efectos en los PERs indicaron una modulación afectiva en ambas modalidades atencionales sin una clara ventaja por parte de ninguna de ellas. Estos efectos se reflejaron de manera serial, y no se encontró ningún efecto significativo de interacción entre endógena y exógena, a favor de una cierta segregación funcional entre ambos sistemas en respuesta a estímulos emocionales. Estos efectos se vieron potenciados por la creación de un contexto a partir de la presentación en bloque de los estímulos objetivo emocionales. No se observó ninguna ventaja de las dimensiones de valencia o arousal de las fotos.

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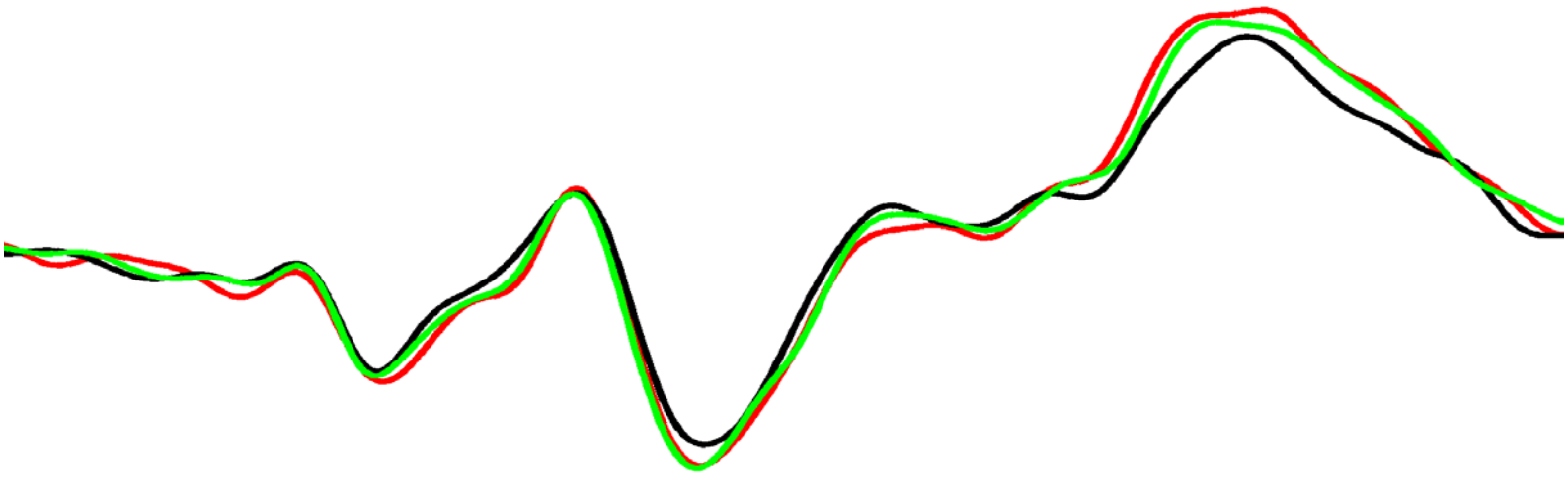
Figure 9. ERP results. Grand averages (depicting all conditions) are shown at FCz and Pz, where the experimental effects may be appreciated. Circled digits represent the temporal sequence of these effects. Significant results at each stage are shown as enlarged detail: 1) Positive Distracters were related to enhanced N2a amplitudes compared to Neutral Distracters, and both Negative and Positive Distracters were associated with enhanced N2p amplitudes; 2) Negative Targets elicited greater LPP amplitudes than Neutral Targets.

PRESENTATION



PRESENTATION

In evolutionary terms, attention is preferentially devoted to emotional events which have proven themselves to be life threatening or life sustaining. In the present Thesis, attention to emotional stimuli will be addressed in the visual domain, presenting pictures of affective scenes; it will be measured through behavioral indices and event-related potentials (ERPs) which, thanks to its millisecond resolution, are especially suitable for exploring rapid attentional processes.

In everyday life, attention is guided by factors related both to the individual and to the stimulus. In order to cope with the complex environment, the nervous system needs to rapidly select information which is relevant to current goals, and also to quickly redirect attention to novel or potentially relevant stimuli. The dynamic interaction of these variables determines final attention allocation in the environment. Accordingly, attention may be divided into two mechanisms: 1) top-down or endogenous attention, which is in charge of the controlled selection of stimuli based on internal and intentional factors (e.g., expectation or current goals), and 2) bottom-up or exogenous attention, which is triggered automatically by stimuli based on its properties (e.g., novelty or potential significance), guaranteeing the detection of important events outside the focus of attention.

Previous studies dealing with endogenous attention to emotional pictures have mainly employed passive viewing paradigms or stimulus categorization tasks (concerning emotional or non-emotional contents of stimuli) with no distracters. Enhanced endogenous attention to emotional targets has been evidenced both at the behavioral and at the neural level; thus, the emotional content of pictures has been reported to alter reaction times and error rates, and to enhance amplitudes of early and, especially, of late ERP components. On the other hand, the effect of emotional distracter pictures on exogenous attention has been analyzed through concurrent but distinct target-distracter (CDTD) paradigms. In these tasks, targets (items to be endogenously attended) and distracters (elements which are irrelevant to the task and may potentially capture exogenous attention) appear at the same time but are physically segregated. When targets are neutral, attentional capture by emotional distracters has been found to produce, at the behavioral level, disruption of the ongoing task (reflected in increased reaction times and error rates) and, at the neural level, larger amplitudes of ERP components reflecting attentional capture.

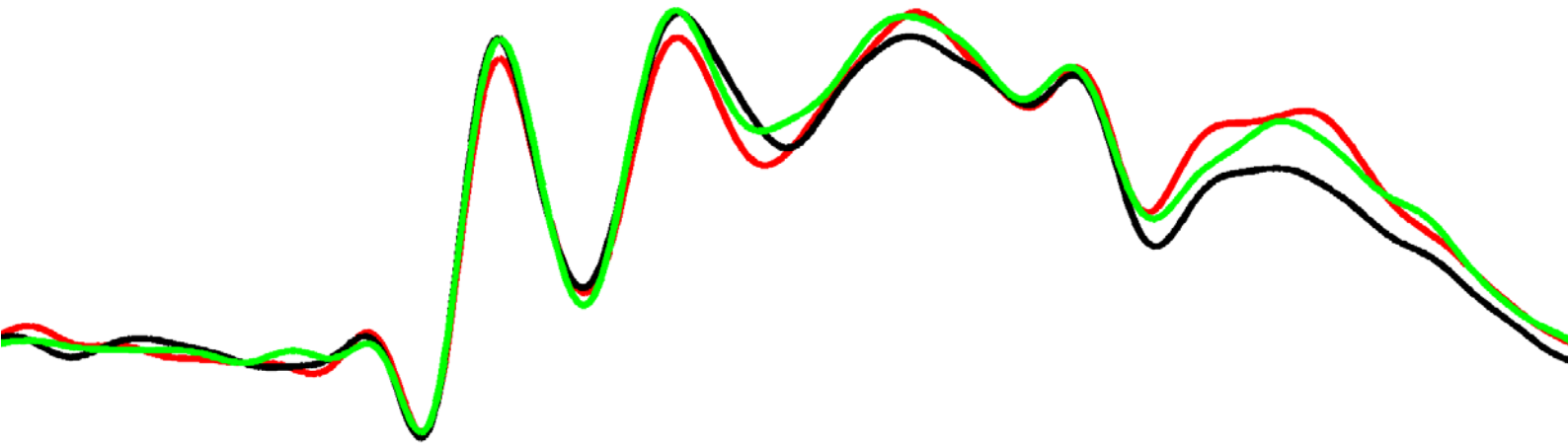
Importantly, these lines of research have been developed independently, in such a way that the simultaneous effect of both emotional targets and distracters has been scarcely explored. Therefore, information on how endogenous and exogenous attention to emotional stimuli compete or interact is lacking up to the moment. Taking into account that, in real situations, emotional events very often play the role of both target and distracter, the analysis of the simultaneous course of endogenous and exogenous attention, when both systems are presented with emotional information, would be a relevant further contribution to the attention and emotion interaction research field. However, to the best of our knowledge, evidence on this topic is very scarce, and there are no electrophysiological studies addressing the detailed temporal course of both concurrent mechanisms. Hence, the principal aim of the present Thesis is to shed light on this issue by presenting emotional targets and distracters simultaneously during a CDTD paradigm, while recording behavioral and electrophysiological indices.

Traditionally, stimulus presentation has usually been fully randomized, in order to control confounding variables. However, while a quick presentation of distracter stimuli resembles quite well real situations, goal-relevant endogenously attended events generally remain for some time, often generating an emotional context. Therefore, a blocked presentation of emotional conditions for targets might possibly be a better approach to a non-laboratory scenario, and might increase ecological validity of the paradigm. Accordingly, the Thesis is composed of two experiments, each of them emphasizing different aspects of the CDTD task design: in Experiment 1, the presentation of target and distracter categories was fully randomized as usual in ERP research dealing with the interaction of attention and emotion, whereas, in Experiment 2, target categories were blocked, adopting a less frequent perspective which attempted to enhance generalizability.

The Thesis begins with a General Introduction reviewing previous behavioral and electrophysiological evidence on endogenous and exogenous attention to emotional stimuli, in which the present work is framed. At the end of the Introduction, open questions concerning the concurrent course of both attentional mechanisms are highlighted, and Objectives and Hypotheses are formulated taking these open issues into account. In the following two chapters, Experiment 1 and Experiment 2 are described and discussed. Subsequently, in the General Discussion section, results of both experiments are discussed in detail and integrated, followed by limitations of the Thesis and proposals for future research on this topic. Finally, the Conclusions are enumerated.

The Thesis was conducted at the Facultad de Psicología of the Universidad Autónoma de Madrid, in the research group "Brain, affect, and cognition" (www.uam.es/CEACO) coordinated by Prof. Luis Carretié.

1 INTRODUCTION



GENERAL INTRODUCTION

1.1. Attention to emotional stimuli

Throughout evolution, in order to ensure the survival of the individual, numerous adaptive tools have been developed at the cognitive level for dealing with biologically salient events. These may be aversive (i.e., life threatening) and appetitive (i.e., life sustaining) environmental cues which, by definition, are emotional. Attention is preferentially allocated to these salient stimuli (e.g., Lang & Bradley, 2010; Öhman, Flykt, & Esteves, 2001; Vuilleumier, 2005). In everyday life, attention is driven by variables both related to the individual, and related to the stimulus. Thus, individuals need to rapidly select sensory information which is relevant to their goals, but also quickly redirect their attention and change their course of action when faced with novel, potentially relevant or motivationally salient stimuli. The dynamic interaction of these factors determines final attention allocation in the environment. Accordingly, attention is controlled by two partially segregated neural systems: an endogenous or top-down system involved in the voluntary selection of sensory information and responses; and an exogenous or bottom-up system automatically recruited by salient events (e.g., Corbetta & Shulman, 2002; Corbetta, Patel, & Shulman, 2008).

The present Thesis will focus on the visual modality, in which the majority of studies on attention to emotional stimuli center. Endogenous or top-down

attention will be assumed when stimuli are task-relevant and attended in a controlled fashion, and exogenous or bottom-up attention when stimuli are task-irrelevant and automatically attended. As will be explained in detail below, behavioral measures have traditionally been used to index attention toward emotional stimuli because they provide observable indices in a simple manner. However, behavior, and the parameters in which it is quantified, such as reaction times and error rates, is the final output of a set of attention-related neural processes (e.g., motor execution, decision making, etc.), which may contribute differently to the behavioral output (e.g., MacNamara, Kappenman, Black, Bress, & Hajcak, 2012). Therefore, ERPs, thanks to its millisecond resolution, are especially useful to disentangle these discrete attention-related neural processes and, indeed, have revealed effects of attentional biases that were not detected behaviorally (Conroy& Polich, 2007; Delplanque, Silvert, Hot, Rigoulot, & Sequeira, 2006; Hajcak, Dunning, & Foti, 2007; MacNamara & Hajcak, 2009; 2010; Olofsson & Polich, 2007; Rozenkrants & Polich, 2008; Schupp et al., 2007a; Wiens, Sand, Norberg, & Andersson, 2011). During the following sections, both attentional systems will be considered, and existing evidence of attention to emotional stimuli from a top-down and a bottom-up approach will be reviewed, before proceeding to describe the interaction of both systems, which will be the focus of the present study.

1.2. Endogenous attention to emotional stimuli

Traditionally, attention has been mainly studied focusing on the top-down or endogenous modality. Endogenous attention describes the attentional process, which enables the voluntary selection of relevant visual stimuli based on internal and intentional factors, such as knowledge, expectation, instructions, or current goals (Corbetta & Shulman, 2002; Corbetta et al., 2008; Posner & Petersen, 1990). This form of selection is referred to by different terms besides endogenous or top-down: selective, voluntary, controlled, active, goal-driven, explicit, or instructed attention. When endogenous attention is directed to the desired object, the

element will be selectively processed, while all other events of the visual scene will remain outside the controlled focus of attention.

Different brain areas, especially those belonging to the dorsal attention network, have been reported to be involved in endogenous attention (Corbetta & Shulman, 2002; Corbetta et al., 2008). During vigilance, the midbrain and the thalamus have been described as key structures (Posner, Rueda, & Kanske, 2007). Further, the anterior cingulate cortex and supplementary motor area have also been found to be active in vigilance or expectancy states (Carretié, Martín-Loeches, Hinojosa, & Mercado, 2001a; Gómez et al., 2001). When attention is voluntarily focused on a stimulus already present, sustained activations in dorsal fronto-parietalregions, as well as in visual areas of the occipital cortex are observed. Endogenous attentional mechanisms are mediated by connections from parietal areas towards sensory cortices, in cooperation with dorsal frontal regions involved in executive control. Specifically, the intraparietal sulcus and frontal eye fields seem to be in charge of sending efferent signals for top-down controlling the activity of visual areas, in order to enhance the processing of selected stimuli (Moore & Armstrong, 2003; Ruff et al., 2006; 2007). The thalamus has been proposed as a gateway structure for these top-down signals to the visual cortex (Petersen, Robinson, & Morris, 1987; Shipp, 2004). When voluntarily attended stimuli are of emotional nature, the ventral prefrontal cortex has been shown to play a key role, and endogenous attention seems to be additionally modulated by the amygdala (Pourtois, Schettino, & Vuilleumier, 2013; Vuilleumier & Huang, 2009). Specifically, the ventral prefrontal cortex, similar to the dorsal part, has been reported as being able to top-down regulate visual attention through efferent neural pathways to sensory cortices (Catani & de Schotten, 2008), enhancing the processing of selected stimuli. Moreover, the amygdala seems also to be able to modulate the activity of visual cortices through direct connections (Adolphs, 2004; LeDoux, 2000; Vuilleumier, Armony, Driver, & Dolan, 2003). Consequently, these control mechanisms seem to result in enhanced activation of visual cortices for emotional compared to neutral stimuli (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004; Carretié et al., 2001a; 2009; Fredrickson et al., 1993;

Kosslyn et al., 1996; Lane et al., 1997; Mourão-Miranda et al., 2003; Pourtois et al., 2004).

Attention to emotional stimuli has also been studied mainly from the endogenous perspective. In general, two kinds of experimental paradigms have been employed in this field; on the one hand, most studies have drawn on passive viewing tasks in which participants are simply instructed to look at the stimuli, and on the other hand, several authors have preferred stimulus categorization tasks (i.e., modified oddball paradigms or other stimulus classification tasks concerning the emotional/ non-emotional content or the spatial orientation of stimuli). Characteristically, all these tasks facilitate endogenous attention to be directed towards emotional stimuli, but emotional content is not always task-relevant. Interestingly, at the neural level, results related to the modulating effect of emotion on endogenous attention are quite similar across all task-designs, though behavioral outcomes may differ, as will be explained during the following sections.

1.2.1. Behavioral evidence

At the behavioral level, existing evidence recorded from stimulus categorization tasks points towards a negativity bias: negative stimuli have been found to modulate reaction times and error rates to a greater extent than neutral or even positive ones. The direction of this modulation may depend on the task-relevance of the emotional information contained in the stimuli. Thus, when emotion was task-relevant, negative stimuli improved performance by eliciting faster reaction times and lower error rates than neutral and, in some cases, positive elements (Chammat, Foucher, Nadel, & Dubal, 2010; Del Zotto & Pegna, 2015; Hajcak, Moser, & Simons, 2006a; Herring, Taylor, White, & Crites, 2011; Rigoulot et al., 2011; Schupp et al., 2007b; Weinberg, Hilgard, Bartholow, & Hajcak, 2012; Wild-Wall, Dimigen, & Sommer, 2008; Yuan et al., 2014; Zhang, Wang, Luo, & Luo, 2012), whereas negative stimuli worsened performance through slower reaction times and higher error rates when emotional information was task-irrelevant (Chai et al., 2012; De Cesarei & Codispoti, 2006, 2011a; Hajcak et al., 2006a; Lichtenstein-Vidne, Henik, & Safadi, 2012; Rossignol et al., 2012).

1.2.2. ERP evidence

Most ERP research concerning endogenous attention to affective stimuli has been conducted during the last two decades, though earlier findings already suggested that pleasant and unpleasant stimuli, compared to neutral ones, could modulate the ERP waveform in a different way. The first studies reporting the influence of emotional visual stimuli on event-related brain responses showed higher amplitudes of a positive-going waveform between 350–450 ms for negative and positive high arousing, compared to neutral low arousing pictures, while participants watched them (Johnston & Wang, 1991; Lifshitz, 1966; Radilová, 1982; Radilová, Figar, & Radil, 1983). Since these first approaches, interest in electrophysiological correlates describing the processing of emotional pictures has been constantly increasing (for a review see Olofsson, Nordin, Sequeira, & Polich, 2008), and research has been progressing due to methodological improvements of both presentation and recording devices, and the development of normative picture stimuli for attention and emotion research such as the *International Affective Picture System* (IAPS; Lang, Bradley, & Cuthbert, 1999), *EmoMadrid* (http://www.uam.es/CEACO/EmoMadrid.htm), the *Geneva Affective Picture Database* (GAPED; Dan-Glauser & Scherer, 2011), or the *Nencki Affective Picture System* (NAPS; Marchewka, Żurawski, Jednoróg, & Grabowska, 2014). Generally, results from ERP studies suggest that endogenous attention is more intensely directed towards emotional contents compared to neutral ones, with amplitude modulations observed at both early and late latencies. Emotional valence appears to influence to a greater extent at early stages of processing, whereas emotional arousal effects are usually relatively late[1] (e.g., Schupp, Flaisch, Stockburger, & Junghöfer, 2006a; see also Olofsson et al., 2008). Valence (ranging from negative or unpleasant to positive or pleasant) and arousal (ranging from calming to arousing) are two theoretically orthogonal affective dimensions, which are widely considered to explain the principal variance of emotional meaning (Lang, Greenwald, Bradley & Hamm, 1993; Osgood, Suci & Tannenbaum, 1957; Russell,

[1] ERP microstate analyses have also evidenced valence effects beginning at 140 ms, whereas arousal effects started at 300 ms (Gianotti, 2008).

1980; Smith & Ellsworth, 1985). Next, specific ERP components showing affective modulation during tasks facilitating endogenous attention to emotional visual stimuli (as indicated, passive viewing tasks or tasks explicitly asking participants to attend the pictures) are described.

1.2.2.1. Earliest modulations (~100 ms)

a) C1

In chronological order, earliest evidence has been provided by studies employing facial expressions indicating effects in the C1 component peaking around 80 ms with a maximum voltage over the occipital pole. Specifically, C1 amplitudes have been reported to reflect an advantage of negative (fearful) faces in early perception (Pourtois, Grandjean, Sander, & Vuilleumier, 2004; West, Anderson, Ferber, & Pratt, 2011). In source localization analyses, C1 has been found to arise from the striate cortex (Clark, Fan, & Hillyard, 1994; Di Russo, Martínez, Sereno, Pitzalis, & Hillyard, 2002; Pourtois et al., 2004). Importantly, it should be taken into account that C1 is highly sensitive to low-level visual characteristics of stimuli, and, especially to the retinotopic position (e.g., Rauss, Schwartz, & Pourtois, 2011).

b) P1

The next component showing significant results in studies dealing with emotional stimuli is the P1 component, which usually peaks between 80 and 120 ms at posterior topographies, and originates in the extrastriate cortex (Clark et al., 1994; Di Russo et al., 2002). Modulation of this component by emotion has also mostly been described for facial expressions, revealing higher amplitudes in response to negative (generally fearful) than neutral faces (Blechert, Sheppes, Di Tella, Williams, & Gross, 2012; Chammat et al., 2010; Conty, Dezecache, Hugueville, & Grèzes, 2012; Pourtois et al., 2004; Pourtois, Thut, de Peralta, Michel, & Vuilleumier, 2005; Rellecke, Sommer, & Schacht, 2012; Rossignol et al., 2012). Larger P1 amplitudes have also been found for negative and/or positive non-facial pictures, compared to neutral ones (Alorda, Serrano-Pedraza, Campos-Bueno,

Sierra-Vázquez, & Montoya, 2007; Keil et al., 2001; Smith, Cacioppo, Larsen, &Chartrand, 2003); however, significant results for pictures are rather scarce at this stage, and actually several other authors have reported a lack of emotional influence on P1 employing pictures (Amrhein, Mühlberger, Pauli, & Wiedemann, 2004; De Cesarei & Codispoti, 2006; Delplanque et al., 2004; Delplanque, Silvert, Hot, & Sequeira, 2005; Junghöfer, Bradley, Elbert, & Lang, 2001; Keil et al., 2002; Olofsson & Polich, 2007; Schupp, Junghöfer, Weike, & Hamm, 2003a; Schupp et al., 2008). Importantly, task settings and combinations of valence or arousal levels were highly variable across these studies, and physical picture properties, which may especially influence early latency outcomes (Alorda et al., 2007; Bradley, Hamby, Löw, & Lang, 2007; Carretié, Hinojosa, López-Martín, & Tapia, 2007), have not always been controlled. Therefore, results at this stage may be considered as less conclusive than those reported for later stages (Olofsson et al., 2008).

1.2.2.2. Latencies up to 300 ms

Components within a latency range from P1 up to 300 ms include N1, P2, N2, Early Posterior Negativity (EPN), and N170:

a) <u>N1, P2, and N2</u>

Taking into account firstly studies separating early stages into several components, evidence concerning N1, P2, and N2 may be cited. N1 usually peaks between 120 and 160 ms, P2 between 160 and 220 ms, and N2 in the range of 220 and 300 ms. Across task designs, all three components have been shown to be sensitive to either valence or arousal of emotional faces and pictures. Specifically, both a negativity bias (largest amplitudes in response to negative stimuli; N1: Delplanque et al., 2004; P2: Carretié et al., 2001a; Carretié, Mercado, Tapia, & Hinojosa, 2001b, Carretié, Hinojosa, Albert, & Mercado,2006; Conty et al., 2012; Delplanque et al., 2004; Huang & Luo, 2007, Olofsson & Polich, 2007; and N2: Carretié, Hinojosa, López-Martín, & Tapia, 2007; Yuan et al., 2014), and a positivity offset (largest amplitudes for positive stimuli; N1: Keil et al., 2002; Yuan et al., 2014; P2: Carretié

et al., 2007; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; and N2: Amrhein et al., 2004; Cuthbert et al., 2000) has been reported for the three components. Additionally, some studies have found larger amplitudes for both negative and positive stimuli, compared to neutral ones (N1: Foti, Hajcak, & Dien, 2009; Franken, Muris, Nijs, & van Strien, 2008; Keil et al., 2001; and N2: Keil et al., 2001; Palomba, Angrilli, & Mini, 1997; Williams, Palmer, Liddell, Song, & Gordon, 2006), and to high arousing compared to less arousing pictures (P2: Junghöfer et al., 2001; and N2: Junghöfer et al., 2001; Rozenkrants & Polich, 2008), evidencing an arousal effect. These effects have been described especially at posterior but also at anterior sites, and, occasionally, some components have presented opposite polarity at anterior and posterior scalp areas. Source localization analyses revealed visual cortices and also the ventro-medial prefrontal cortex as its origin (Carretié et al., 2001a; 2006; 2007; Keil et al., 2002). In conclusion, all three components (N1, P2, and N2) have been reported to be sensitive to endogenous attention towards emotional stimuli, though effects are rather diverse; this may be due to differences in experimental designs but also in quantification methods (i.e., components are quantified across studies in different time windows and employing both area and peak measures which may be insensitive to component overlap). Finally and importantly, latencies of the reported components concur with the time window of another component described next, so that results cannot be clearly discriminated from each other.

b) EPN

EPN is one of the most cited components in endogenous attentional studies employing emotional stimuli, and shows quite convergent results across studies and experimental designs. The time window of EPN usually starts after the descending slope of P1 and lasts until the beginning of the late positive waveform (approximately from 150 to 300 ms, though the onset varies between studies). Given this wide time window, EPN may actually include more than one component. However, it is globally analyzed since it generally shows the same amplitude modulation in the whole range. Specifically, it appears as a relative negative

deflection at temporo-occipital sites, which is more negative for emotional than for neutral stimuli among the whole window; at fronto-central sites it may be inverted. This modulatory effect of emotion has been frequently reported (Alorda et al., 2007; Bublatzky, Gerdes, White, Riemer, & Alpers, 2014; Codispoti, Ferrari, & Bradley, 2007; Foti et al., 2009; Flaisch, Junghöfer, Bradley, Schupp, & Lang, 2008a; Flaisch, Stockburger, & Schupp, 2008b; Hajcak & Nieuwenhuis, 2006b; Rellecke et al., 2012; Sabatinelli, Keil, Frank, & Lang, 2013; Schupp et al., 2003a; 2008; Schupp, Markus, Weike, & Hamm, 2003b; Wronka & Walentowska, 2011), though many studies have also found additional differences between positive and negative stimuli, which imply an advantage of positive over negative information (Amrhein et al., 2004; De Cesarei & Codispoti, 2006; Franken et al., 2008; Pastor et al., 2008; Schupp, Junghöfer, Weike, & Hamm, 2004a; Schupp, et al., 2006b; 2007a; 2007b; Schupp, Schmälzle, Flaisch, Weike, & Hamm, 2013). Moreover, when employing facial expressions, an advantage of negative compared to neutral stimuli may appear (Blechert et al., 2012). Though emotional effects on EPN appear in several passive and active tasks, they are maximal during passive rapid serial visual presentation paradigms (Flaisch et al., 2008a; 2008b; Schupp et al., 2003a; 2006b; 2007a; 2007b; 2008). The component has been located in temporo-parieto-occipital areas (Junghöfer et al., 2001; Schupp et al., 2006; 2007a; 2007b).

The reported emotional effects at early latencies are independent from task relevance of the emotional stimulus content (Schupp et al., 2006a). However, when designing the task, it should be considered that, at these early stages, waveform modulations may be sensitive to task demands (Schupp et al., 2007b), and to stimulus properties (i.e., size, De Cesarei & Codispoti, 2006; complexity, Bradley et al., 2007; spatial frequency, Alorda et al., 2007; or visual noise, Schupp et al., 2008), which should be controlled.

c) N170

The N170 component has been consistently reported in studies employing facial expressions. It typically peaks between 130 and 200 ms, showing enhanced amplitudes for facial compared to non-facial stimuli at posterior lateral scalp areas

(Bentin, Allison, Puce, Perez, & McCarthy, 1996; Itier & Taylor, 2004a; Rousselet, Macé, & Fabre-Thorpe, 2004). Although some studies failed to show any effect of emotional faces on N170 (e.g., Chai et al., 2012; Chammat et al., 2010; Hirai, Watanabe, Honda, Miki, & Kakigi, 2008; Wronka & Walentowska, 2011), numerous recent studies have described enhanced N170 amplitudes in response to emotional compared to neutral faces, where fearful, angry, and sad faces were employed as negative expressions, and happy faces as positive expressions. Specifically, the advantage of fearful and angry compared to neutral faces is the most cited result among these studies (Bediou, Eimer, d'Amato, Hauk, & Calder, 2009; Blechert et al., 2012; Conty et al., 2012; Del Zotto, & Pegna, 2015; Herbert, Sfärlea, & Blumenthal, 2013; Rigoulot et al., 2011; Smith, 2012; Yuan, Zhou, & Hu, 2014; Zhang et al., 2012; Zhao & Li, 2006; see a review in Hinojosa, Mercado, & Carretié, 2015). However, it should be noted that most of them have only employed negative expressions as emotional stimuli, in the absence of positive expressions. When negative and positive faces were presented together during the same task, along with neutral ones, both emotional stimuli have generally shown an advantage compared to neutral ones (Bublatzky et al., 2014; Morel, Ponz, Mercier, Vuilleumier, & George, 2009; Mühlberger et al., 2009; Rellecke et al., 2012; Rossignol et al., 2012; Smith, 2012; Tortosa, Lupiáñez, & Ruz, 2013; Wild-Wall et al., 2008; Williams et al., 2006; see Hinojosa et al., 2015 for a review). Although the reported effects appear in both direct and indirect viewing and categorization tasks, they are maximal when the emotional expression is not task-relevant (Hinojosa et al., 2015). Source localization analyses have evidenced that the component originates in face processing areas, such as the superior temporal sulcus and the fusiform gyrus (Itier & Taylor, 2004b; Sadeh, Podlipsky, Zhdanov, & Yovel, 2010).

1.2.2.3. Late positivities

The most important late component in relation to endogenous attention to emotional stimuli is in fact a set of late positivities often known as the Late Positive Complex (LPC), which begins around the end of EPN and may be sustained for the

time of stimulus presentation or even beyond. In some studies, it has been separated in several individual components, including the P3 (or P3a) component, the Late Positive Potential (LPP) or P3b, and the Positive Slow Wave (PSW).

a) P3

P3 is usually, but not only, elicited in Oddball and stimulus categorization tasks. It peaks around 300-400 ms at posterior scalp regions and, as earlier components, has shown largest amplitudes in response to negative (Delplanque et al., 2006; Foti et al., 2009; Rozenkrants et al., 2008; Williams et al, 2006), positive (Carretié et al., 2001a; 2006; Cuthbert et al., 2000; Keil et al., 2002; Yuan et al., 2014), or both negative and positive pictures (Alorda et al., 2007; Amrhein et al., 2004; Mini, Palomba, Angrilli, & Bravi, 1996; Olofsson & Polich, 2007; Palomba el al., 1997; Tortosa et al., 2013). Source localization analyses have revealed visual association cortex sources for this component (Carretié et al., 2001a; 2006).

b) LPP and PSW

LPP (sometimes labeled P3b, mainly in stimulus categorization tasks) is the most characteristic ERP component in relation to endogenous attention to emotional stimuli. It appears as a positive deflection starting around 400 ms which can extend for seconds, depending on the task. From approximately 800 ms it is usually called PSW. Its characteristic topography is centro-parietal (though it also can be observed at frontal and occipital sites). It consistently shows more positive amplitudes to emotional (negative and positive) than to neutral pictures and faces, which has been reported throughout several task designs (Alorda et al., 2007; Amrhein et al., 2004; Bernat, Cadwallader, Seo, Vizueta, & Patrick, 2011; Bublatzky et al, 2014; Chai et al., 2012; Codispoti, Ferrari, & Bradley, 2006; Codispoti et al, 2007; Codispoti, Mazzetti, & Bradley, 2009; De Cesarei & Codispoti, 2006; 2011b; Delplanque et al., 2006; Dolcos & Cabeza, 2002; Ferrari, Bradley, Codispoti, & Lang, 2011; Ferrari et al., 2016; Flaisch et al., 2008b; Franken et al., 2008; Gable, Adams, & Hajcak, 2015; Hajcak et al., 2006a; 2007; Hajcak & Nieuwenhuis, 2006b; Hajcak

& Olvet, 2008; Herbert et al, 2013; Keil et al., 2001; Mini et al., 1996; Mühlberger et al., 2009; O'Hare, Atchley, & Young, 2016; Olofsson & Polich, 2007; Pastor et al., 2008; Rellecke et al., 2012; Sabatinelli, Lang, Keil, & Bradley, 2007; Sabatinelli et al., 2013; Schönfelder, Kanske, Heissler, & Wessa, 2014; Schupp et al., 2003b; 2004a; 2004b; 2013; Weinberg et al., 2012; Wood & Kisley, 2006). Therefore, LPP is thought to reflect an arousal effect; indeed, it shows higher amplitudes to more than to less arousing stimuli (Cuthbert et al., 2000; Rozenkrants et al., 2008; Schupp et al., 2000), and the emotional effect disappears when balancing arousal between emotional and neutral stimuli (Conroy & Polich, 2007). Nevertheless, some studies have also found (valence) differences between negative and positive stimuli, the highest amplitudes being observed in response to negative (Blechert et al, 2012; Bradley et al., 2007; Carretié et al., 2006; Delplanque et al., 2005; Foti et al., 2009; Ito, Larsen, Smith, & Cacioppo, 1998; Keil et al., 2002; Schupp et al., 2004; Wood & Kisley, 2006) or positive stimuli (Cuthbert et al., 2000; Delplanque et al., 2004; Keil et al., 2002; Palomba et al., 1997). The origin of LPP has been reported in posterior frontal and temporo-parieto-occipital areas (Carretié et al., 2006; Keil et al., 2001; 2002; Sabatinelli et al., 2007). Task-relevance and emotion show additive effects on LPP amplitude, but task-irrelevant emotional stimulus content also causes significant effects (see Ferrari, Codispoti, Cardinale, & Bradley, 2008; Schupp et al., 2007a). Further, affective modulation of this component is observed regardless of perceptual differences in size (De Cesarei & Codispoti, 2006; 2011a), complexity (Bradley et al., 2007), or spatial frequency (Alorda et al., 2007), and is also relatively independent from task demands (Hajcak et al., 2007) or fatigue (Olofsson & Polich, 2007).

1.2.3. Conclusions

In summary, at the behavioral level, existing data concerning endogenous attention to emotional faces and pictures support a negativity bias; thus, negative stimuli seem to affect reaction times and error rates to a greater extent than neutral or even positive ones. At the neural level, evidence at late latencies is quite conclusive, indicating a modulatory effect of emotional (both negative and

positive) stimuli on LPC amplitudes. At early latencies, despite the variety of results, there is also clear evidence in favor of emotion modulating early neural responses between 100 and 300 ms, with no apparent advantage of negative or positive stimuli. These emotional effects can be observed during both passive viewing and active stimulus categorization tasks, and regardless of task-relevance of the emotional content.

1.3. Exogenous attention and emotion

Data regarding affective modulation of bottom-up or exogenous attention are more recent and relatively scarce, compared to endogenous attention. Exogenous or bottom-up attention (also called automatic, passive, stimulus-driven, implicit, or reflexive) is triggered automatically by factors related to the saliency of stimulation, —such as intensity, novelty, or potential relevance— (Corbetta & Shulman, 2002; Corbetta et al., 2008; Yantis, 1993). This kind of attention assures the detection of salient and potentially significant stimuli outside the current focus of attention, the interruption of endogenous attention to the current target, and its reorientation towards the distracter; it is, therefore, crucial from an adaptive point of view. Hence, exogenous attention, by definition, is composed of three subprocesses: 1) preattention, 2) attentional capture (or reorienting), and 3) sensory amplification (or direction of endogenous attention to the distracter). The first and the second stage are entirely automatic, whereas in the third stage may also concur controlled attention.

Exogenous attention is supported by different neural networks including the dorsal and ventral attention networks (Corbetta & Shulman, 2002; Corbetta et al., 2008). *Preattentional processes* seem to involve the ventral prefrontal cortex. This area is able to very rapidly (from 100 ms after stimulus onset) respond to visual events (Carretié, Hinojosa, Mercado, & Tapia, 2005; Kawasaki et al., 2001; Northoff et al., 2000), apparently thanks to afferent magnocellular pathways directly from the visual cortex, from some thalamic nuclei (Bar, 2003; Bar et al., 2006), and also from the amygdala (Emery & Amaral, 2000). These connections would allow a very fast detection of relevant stimuli in the environment. Further, it

has been suggested that the ventral prefrontal cortex may be subsequently capable of top-down regulating visual attention through efferent neural pathways to visual cortices (Catani & de Schotten, 2008) which facilitates *sensory amplification*. Additionally, the amygdala also receives magnocellular information (Vuilleumier et al., 2003), and should therefore also be able to modulate the activity of sensory areas through similar pathways towards visual cortices (Adolphs, 2004; LeDoux, 2000) allowing sensory amplification as well. When distracters are of emotional nature, these efferent projections from the prefrontal cortex, the amygdala, and also from the anterior insula (Rodman & Consuelos, 1994) seem to allow an enhanced activation of ventral visual cortices compared to neutral stimuli (Carretié et al., 2001a; 2004; 2009; Fredrickson et al., 1993; Kosslyn et al., 1996; Lane et al., 1997; Mourão-Miranda et al., 2003; Pourtois et al., 2004). When employing stimuli others than faces, higher activation has also been observed in dorsal areas of the visual cortex (Carretié et al., 2001a; 2009; Kosslyn et al., 1996; Lang et al., 1998). *Reorientation* has been located in the parietal cortex, traditionally related to spatial location. Two areas seem to be especially involved in this response: the superior parietal lobe, responsible for the attention orientation to relevant events (Corbetta et al. 2008), and the temporo-parietal junction, which allows the disconnection from the current attentional focus (Posner et al., 2007). Additionally, the frontal eye fields and the superior colliculus have been found to be in charge of directing the eyes towards the relevant stimulus (Posner et al., 2007). Moreover, distracters capturing attention may also activate the dorsal prefrontal cortex and the anterior cingulate cortex, if the capture generates a conflict between the distracter and other endogenously attended stimuli (De Fockert, Rees, Frith, & Lavie, 2004; Egner, Etkin, Gale, & Hirsch, 2008; Ochsner et al., 2009).

Visual experimental tasks exploring exogenous attention to emotional stimuli typically consist of CDTD paradigms (also named directed attention tasks; MacNamara et al., 2012). In these tasks, targets (i.e., elements to which participants are asked to direct endogenous attention) and distracters (i.e., elements irrelevant to the task but that may potentially capture exogenous

attention) appear at the same time but are physically segregated. In the studies reviewed below, a variety of elements have been employed as targets (e.g., digits, letters, words, geometrical figures, pictures), while distracters have always been emotional pictures or faces presented at locations which were not endogenously attended. As indicated, evidence is rather scarce, compared to the amount of studies exploring endogenous attention to emotional stimuli. Additionally, most studies have used only unpleasant and neutral stimuli as distracters, and there is less evidence concerning pleasant stimuli, so that results are slightly biased towards negativity probably, at least in part, due to this methodological bias.

1.3.1. Behavioral evidence

At the behavioral level, automatic capture of attentional resources by emotional distracters is reflected in increased reaction times and error rates during the ongoing task. As in the case of endogenous attention, existing evidence points to a negativity bias: negative distracter pictures seem to interfere with performance in the main task to a greater extent than neutral or even positive ones. However, as indicated, studies employing both negative and positive distracters are quite scarce. Specifically, when negative distracters were presented on the screen, reaction times and/or error rates in the ongoing task were significantly augmented compared to the presentation of neutral and, in some studies, positive distracters (Buodo, Sarlo, & Munafò, 2010; Carretié, Ruiz-Padial, López-Martín, & Albert, 2011, Carretié et al., 2012; Keil, Moratti, Sabatinelli, Bradley, & Lang, 2005; MacNamara & Hajcak, 2009; 2010; Pourtois, Spinelli, Seeck, & Vuilleumier, 2010; Schönwald & Müller, 2014; Tiferet-Dweck et al., 2016; Vromen, Lipp, Remington, & Becker, 2016). However, other studies reported highest attentional capture by positive (Feng, Wang, Wang, Gu, & Luo, 2012), or by both negative and positive distracters (Calvo & Nummenmaa, 2011; Gilboa-Schechtman, Foa, & Amir, 1999; Hodsoll, Viding, & Lavie, 2011; Junhong, Renlai, & Senqi, 2013; Müller, Andersen, & Keil, 2008;Müller, Andersen, & Attar, 2011).

1.3.2. ERP evidence

Generally, results from ERP studies have shown that exogenous attention is preferentially captured by emotional stimulus contents, compared to neutral contents, and this modulation is observed especially at early latencies, reflecting preattention, reorienting, and sensory amplification (see a review in Carretié, 2014).

1.3.2.1. Earliest modulations (~100 ms)

In chronological order, earliest evidence of exogenous attention towards emotional pictures has been found in the P1 component, which usually peaks around 100 ms. Specifically, larger P1 amplitudes at posterior topographies have been reported when negative, compared to neutral distracters were presented (Carretié et al., 2004; 2009). This component originates in the occipital cortex (Di Russo et al., 2002), probably reflecting sensory amplification. However, other authors have indicated a lack of evidence in favor of affective modulations at these early latencies (Buodo et al., 2010; Nordström & Wiens, 2012; Schönwald & Müller, 2014). Importantly, and as has been mentioned above, results at this early stage are less consistent than those reported at later stages, probably due to differences in task settings, and due to the use of stimuli with different physical properties, which may especially influence early latencies (Alorda et al., 2007; Bradley et al., 2007; Carretié et al., 2007).

1.3.2.2. Latencies up to 300 ms

As in endogenous attention studies, components showing latencies between the offset of P1 and 300 ms include N1, P2, N2, EPN, and N170.

a) <u>N1, P2 and N2</u>

In relation to N1, up to day no evidence has been found so far supporting that this component is sensitive to exogenous attention to emotional stimuli, though it

actually has not always been analyzed. In turn, there are a variety of results concerning P2 (peaking at 160–200 ms) at anterior regions, and the family of N2 components (peaking around 250ms) at wider topographies. Specifically, anterior P2 has shown largest amplitudes elicited by negative (Carretié et al., 2011; 2012; Holmes, Kiss, & Eimer, 2006; Junhong et al., 2013), positive (Feng et al., 2012), or by both negative and positive distracters, compared to neutral ones (Carretié et al., 2004). Moreover, the N2 family —including N2, fronto-temporal N2 or N2ft, and parieto-contralateral N2 or N2pc— has been reported to be sensitive to negative (Carretié et al., 2013; Buodo et al., 2010; Eimer & Kiss, 2007), positive (Carretié et al., 2004; Feng et al., 2012), or negative and positive distracters (López-Martín, Albert, Fernández-Jaén & Carretié, 2013). Source localization analyses revealed that anterior P2 and the N2 family originate in distinct structures: some sources are located in cortical areas and potentially intervene in preattention (Carretié et al., 2013), others in structures belonging to the dorsal and ventral attention networks possibly involved in reorienting (Carretié et al., 2013; Carretié et al., 2012; Schönwald & Müller, 2014), and others in visual cortices probably reflecting sensory amplification (Carretié et al., 2004; Carretié et al., 2012; Schönwald & Müller, 2014).

Attentional capture by emotional distracters during these early latencies seems not to depend on task demands, given that significant results are even reported for tasks with relatively low accuracies (Müller et al., 2008; Schönwald & Müller, 2014). In contrast, several other factors may influence results and may determine whether these components are present in the ERP and whether they show significant effects. On the one hand, picture physical properties, such as spatial frequencies have shown to play a key role when determining the magnitude of attentional capture by emotional stimuli (Carretié, Ríos, Periáñez, Kessel, & Álvarez-Linera, 2012). On the other hand, spatial location of stimuli has also been reported as critically influencing outcomes, especially in the case of the N2 family of components; thus, N2pc has only been observed in response to lateralized stimuli (Eimer, 1996; Luck & Hillyard, 1994), while N2ft has been found to be maximal when distracters are more centrally presented (Carretié et al., 2013).

Therefore, both physical properties and spatial distribution of stimulation should be taken into account when interpreting findings at these latencies.

b) EPN

Several studies have also explored the temporo-occipital EPN in relation to exogenous attention to emotional stimuli, and results have indicated larger amplitudes in response to negative (Nordström & Wiens, 2012; Schönwald & Müller, 2014), or both negative and positive distracters (De Cesarei, Codispoti, & Schupp, 2009; Wiens & Syrjänen, 2013). The origin has been located in temporo-parieto-occipital areas with a maximum in visual cortices (Schönwald & Müller, 2014). However, the described modulation by emotional distracters has been found only when distracters were presented at fixation; when they were presented at other locations, the EPN effect has not been evident (Schupp et al., 2013; Wiens et al., 2011). Thus, it cannot be discarded that EPN more properly indexes endogenous than exogenous attention to emotional stimuli, since distracters presented at fixation may probably be not completely unattended.

c) N170

Evidence on exogenous attention concerning the face-sensitive N170 component is remarkable scarce and divergent. One study has reported enhanced N170 amplitudes to negative compared to neutral background faces (Jiang et al., 2009), while another study has found higher amplitudes in response to positive than to negative —but not to neutral— distracter faces (Carretié et al, 2012). A third study failed to demonstrate significant differences between faces (Holmes, Kiss, & Eimer, 2006), though it should be noted that, in this study, distracters were presented at fixation.

1.3.2.3. Late positivities

The scarce data existing on late positivities in studies exploring exogenous attention to emotional stimuli are focused on LPP. There is also evidence of enhanced parieto-occipital LPP amplitudes elicited by negative (Nordström & Wiens, 2012; Wiens et al., 2011; Schönwald & Müller, 2014), positive (Feng et al., 2012), or both negative and positive distracters (De Cesarei et al., 2009; Syrjänen & Wiens, 2013; Wiens & Syrjänen, 2013), originating in occipito-temporal areas (Schönwald & Müller, 2014). However, except one (Schönwald & Müller, 2014), all studies reporting LPP findings presented emotional distracters at fixation; thus, as in the case of EPN, endogenous attention cannot be discarded as contributing to these results. Indeed, studies in which the distracter was placed at other locations have reported a lack of LPP effects (MacNamara & Hajcak, 2009; 2010; Schupp et al., 2013). Furthermore, it has been proposed elsewhere that, —without discarding the influence of automatic processes on LPP—, this component is reflecting endogenous rather than exogenous attention to the distracter (Hajcak et al., 2009; see a review in MacNamara et al., 2012).

1.3.3. Conclusions

In summary, at the behavioral level, existing evidence in favor of exogenous attention towards emotional distracters points to a negativity bias; thus, negative distracters seem to interfere with performance in the main task to a greater extent than neutral or even positive ones. At the neural level, despite the scarce number of studies which have explored exogenous attention to emotional distracters, quite consistent conclusions may be drawn from the results. Specifically, exogenous attention to emotional distracters in CDTD tasks seems to be reflected at early latencies, especially influencing the anterior P2 and the family of N2 components, which have shown larger amplitudes in response to negative and positive distracters.

1.4. Open questions addressed in this Thesis

During the previous sections, the existing evidence on the effect of emotional visual stimuli on attention —measured through behavioral combined with electrophysiological indices— has been reviewed for the endogenous and exogenous modalities. At the behavioral level, a negativity bias was the most reported result both in endogenous and exogenous attention studies. At the neural level, it has been concluded that the modulatory influence on endogenous attention elicited by emotional targets may be observed both at early (< 300 ms) and at late (> 300 ms) stages of processing, whereas the effect on exogenous attention generated by emotional distracters has been especially evident at early (< 300 ms) latencies. So far, although the number of studies exploring endogenous attention is significantly larger, conclusions concerning both approaches rely on clear evidence.

Taking into account this evidence, an interesting further step in order to move on in the field would be an analysis of the competition of endogenous and exogenous attention to emotional stimuli, i.e., an exploration of the two attentional responses when both emotional targets and emotional distracters are simultaneously presented. However, behavioral data on this issue are remarkable scarce, and, to the best of our knowledge, the detailed temporal course of this competition is still unexplored. Moreover, the role of the valence and arousal dimensions of stimuli is unclear. Thus, the aim of the present Thesis is to shed light on this issue by simultaneously presenting emotional task-relevant and task-irrelevant pictures during a CDTD paradigm. The general scopes, taking into account both behavioral and neural (ERP) data, are three: 1) to explore how the endogenous-exogenous competition is resolved at the behavioral level and whether there is any advantage of one system over the other; 2) to disentangle the neural time course of the concurrent attention effects, discovering if both responses are reflected in the ERP in a parallel manner or in a serial order; 3) to analyze how valence and arousal of stimuli modulate competing endogenous and exogenous attention. A potential interaction effect between both modalities will also be studied (an example of such an interaction effect would be the reduction of

the attentional capture caused by emotional distracters during endogenous attention to an emotional target).

The Thesis is composed of two experiments, each of them emphasizing different aspects of the task design; in Experiment 1, target and distracter presentation was fully randomized, whereas, in Experiment 2, target categories were blocked. Nearly all studies reviewed above, both at the endogenous and at the exogenous level, have displayed emotional and neutral pictures in random order. Random stimulus presentation is clearly the most extended praxis in this research field and, in general, in Cognitive and Affective Neuroscience. Therefore, and in order to obtain data that may be compared with those usually obtained in this area of research, Experiment 1 employed a random task design in which emotional and neutral targets and distracters were randomly combined. Nevertheless, in real situations emotional stimuli attracting our attention are often long-lasting, frequently generating an emotional context (i.e., providing the current visual scene with an affective content). Emotional contexts have previously been reported to potentiate attentional processes towards both neutral and emotional information (Cuthbert, Schupp, Bradley, McManis, & Lang, 1998; Diéguez-Risco, Aguado, Albert, & Hinojosa, 2013; 2015; Domínguez-Borràs et al., 2009; Hietanen & Astikainen, 2013; Ito et al., 1998; Kuniecki, Pilarczyk, & Wichary, 2015; Righart & de Gelder, 2006; 2008a; 2008b; Rothermund, Wentura, & Bak, 2001; Schupp et al., 2000; Smith et al., 2006; Van Dessel & Vogt, 2012). Accordingly, a block design was employed in Experiment 2 for the presentation of emotional targets, in order to provide ecological validity and to explore how emotional contexts modulate the endogenous-exogenous competition. Consequently, results of both experiments will contribute via two complementary approaches.

The emotional content of targets will not be task-relevant during either Experiment 1 or Experiment 2, in order to ensure an indirect effect of emotion. Direct tasks —as regards affective content of stimulation— (i.e., pressing different keys as a function of the emotional content) may lead participants to consider that emotional stimuli are more important than neutral stimuli. This may result in the 'relevance-for-task effect', which is known to modulate ERP amplitudes (e.g.,

Duncan-Johnson & Donchin, 1977). Emotion will be defined in terms of valence and arousal, and the term 'emotional' will refer to both negative and positive stimuli that are greater than neutral ones in arousal; in turn, arousal will be matched among unpleasant and pleasant stimuli. Although previous studies have mostly operationalized emotion through both facial expressions and scene pictures, as reviewed above, the latter were preferred for the present design, because scene pictures have been shown to better resemble the two-dimensional affective space[2]. Accordingly, during both Experiment 1 and Experiment 2 emotional scenes will be employed as stimuli, and results will be discuss based on this kind of evidence[3].

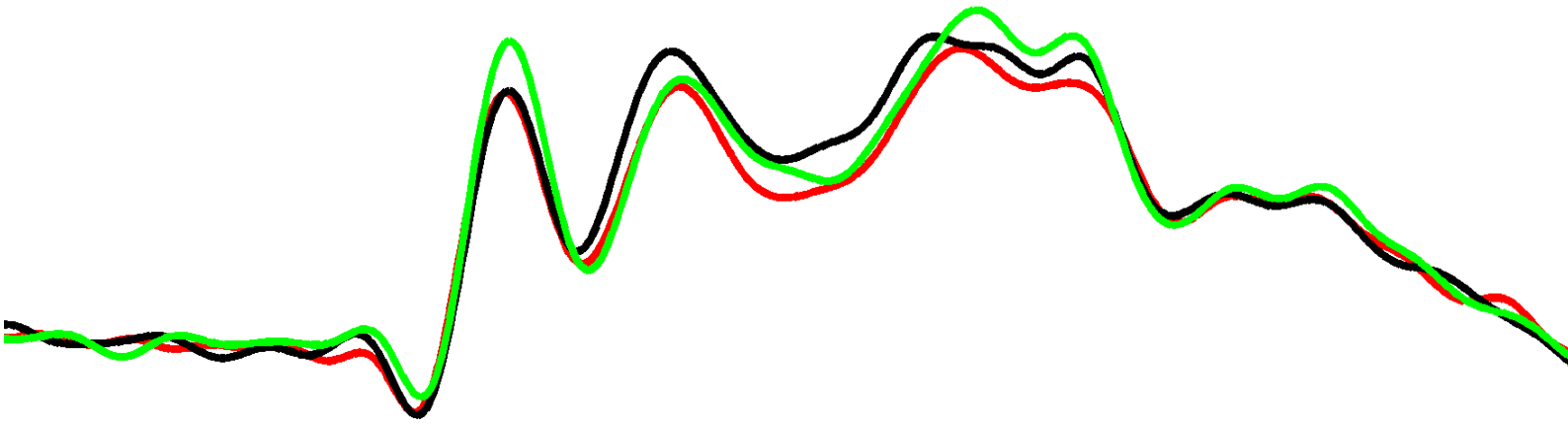
As has been already indicated, the first objective of the present Thesis was to explore how the competition between endogenous and exogenous attention is reflected at the behavioral level. Based on previous evidence showing that negative target and negative distracter content seems to be the one mostly interfering with performance when emotional information is task-irrelevant (Buodo et al., 2010; Carretié et al., 2011; 2012; De Cesarei & Codispoti, 2006; 2011a; Hajcak et al., 2006a; Keil et al., 2005; Lichtenstein-Vidne et al., 2012; MacNamara & Hajcak, 2009; 2010; Schönwald & Müller, 2014; Tiferet-Dweck et al., 2016; Vromen et al., 2016), it was expected that both negative target and distracter pictures, rather than neutral or even positive ones, would elicit slower reaction times and higher error rates in the stimulus categorization task. With respect to the advantage of one system over the other and a potential interaction effect, previous behavioral data are too scarce to formulate a specific hypothesis. The second scope was to disentangle the neural time course of the concurrent attention effects. Previous studies have shown that both emotional targets and distracters, compared to

[2]Scene pictures have been proved to be more powerfully related to motivational imperatives than more simple figures or facial stimuli, which are generally less arousing and elicit more moderate affective reactions (Britton, Taylor, Sudheimer, & Liberzon, 2006; Cloitre, 1992; Zlomke & Davis, 2008).

[3] Taking into account previous data, it seems reasonable to separately consider evidence from studies using affective scenes and evidence obtained from facial expressions. Specifically, perceptual and attentional studies comparing effects of emotional faces and scenes at the behavioral and neural level have found a considerable impact of stimulus class on the resulting emotion effects, obtaining partially different results (Carretié et al., 2012; Olatunji, Armstrong & Ciesielski, 2015; Sabatinelli et al., 2011; Thom et al., 2014).

neutral ones, consistently manifest its influence on early latencies; thus, negative and positive targets have been reported as prompting higher N1, P2, N2, and EPN amplitudes (e.g., Carretié et al., 2001a; Codispoti et al., 2007; Cuthbert et al., 2000; Olofsson & Polich, 2007; Schupp et al., 2013), and negative and positive distracters usually elicited effects in P2 and N2 (Buodo et al., 2010; Carretié et al., 2004; 2011; 2012; Feng et al., 2012; see a review in Carretié, 2014). Additionally, numerous studies have evidenced an impact of both negative and positive targets at late latencies, reflected especially in LPP (e.g., Amrhein et al., 2004; Codispoti et al., 2006; De Cesarei & Codispoti, 2011b; Delplanque et al., 2006; Ferrari et al., 2016; Hajcak et al., 2007; Keil et al., 2001; Sabatinelli et al., 2013; Schupp et al., 2003b). Consequently, it was hypothesized that endogenous attention to emotional stimuli, rather than to neutral ones, would be reflected at early latencies (N1, P2, N2,and/or EPN), as well as at late latencies (LPP); exogenous attention to emotional stimuli, compared to neutral stimuli, would be manifested only at early stages (P2 and/or N2). Based on the existing evidence, no hypothesis could be defined about the temporal exogenous-endogenous sequence (particularly at early latencies) or about a potential interaction effect. The third objective was to analyze the modulating effect of stimulus valence and stimulus arousal on the exogenous-endogenous competition. As shown by previous studies, valence influences ERPs to a greater extent at early stages of processing, whereas arousal effects are usually relatively late (e.g., Gianotti, 2008; Schupp, Flaisch, Stockburger, & Junghöfer, 2006a; see a review in Olofsson et al., 2008), thus, the same effect pattern was expected here. Fourth, the present Thesis aimed at comparing a random and a block design of the CDTD task. The blocked design was employed in order to generate an emotional context, which has previously been reported to improve attention to emotional stimuli (Cuthbert et al., 1998; Diéguez-Risco et al., 2013; 2015; Domínguez-Borràs et al., 2009; Hietanen & Astikainen, 2013; Ito et al., 1998; Kuniecki et al., 2015; Righart & de Gelder, 2006; 2008a; 2008b; Rothermund et al., 2001; Schupp et al., 2000; Smith et al., 2006; Van Dessel & Vogt, 2012). Hence, it was hypothesized that experimental effects observed employing the random task design would result amplified when using the contextual design.

2 OBJECTIVES & HYPOTHESES



OBJECTIVES AND HYPOTHESES

2.1. Objectives

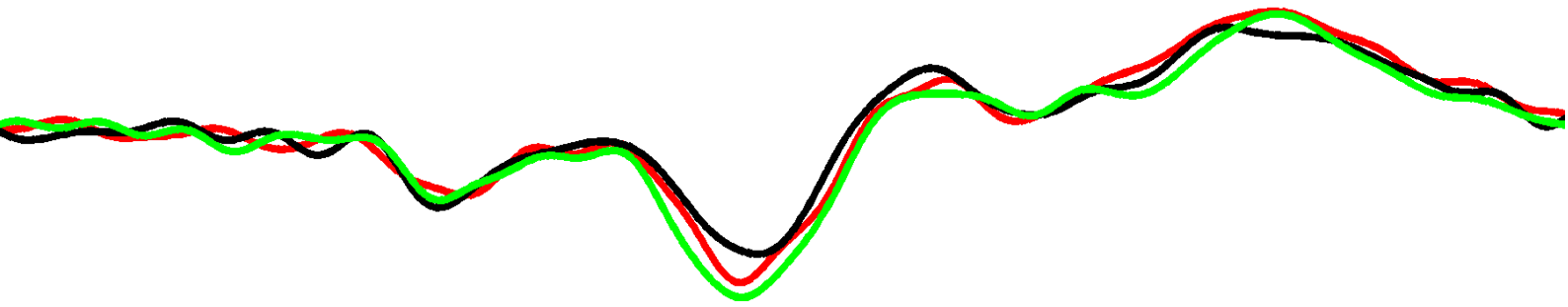
1. To explore how the competition between endogenous and exogenous attention is reflected at the behavioral level, and whether there is any advantage of one modality over the other and/or any interaction effect.
2. To disentangle the neural time course of the competing attention effects, and to determine whether both responses are reflected in the ERP in a parallel manner or in a serial order.
3. To analyze how valence and arousal of stimuli modulate the exogenous-endogenous competition.
4. To compare the influence of a random versus a block (contextual) design on competing endogenous and exogenous attention.

2.2. Hypotheses

1. Increased reaction times and/ or error rates will be observed in response to negative targets and to negative distracters, compared to neutral ones.
2. Emotional targets will yield higher amplitudes than neutral ones at both early (N1, P2, N2, and/or EPN) and late latencies (LPP); emotional distracters, in comparison with neutral ones, will produce enhanced amplitudes only in early components (P2 and/or N2).

3. Valence will modulate ERPs at early latencies (N1, P2, N2, and/or EPN), whereas arousal effects will appear at late latencies (LPP).
4. Experimental effects revealed by the random task design (Experiment 1) will be amplified when using the contextual design (Experiment 2).

3 EXPERIMENT 1



ABSTRACT

Previous data show an advantage of emotional stimuli during endogenous and exogenous attentional processes. However, this evidence is based on studies analyzing the two attentional modalities separately, and there is little proof of the way in which they modulate each other when both are confronted with emotional stimuli. The present study explored this issue through behavioral and ERP measures. To this end, participants (N=31) performed a target-distracter task, during which they were asked to indicate whether two identical negative, neutral, or positive pictures were presented in mirror orientation or not. These pictures were placed in the center of the screen against a background with a negative, neutral, or positive distracter image, which was irrelevant for the primary task. Emotional contents of targets and distracters were randomly combined. Analyses on behavioral data yielded an effect of the emotional valence of targets, which was evidenced by higher error rates for negative targets than for neutral and positive ones. Neural results revealed a modulatory effect of the emotional content of targets (i.e., endogenous attention) at early (N2a, peaking at 140 ms) and at late (LPPa and LPPp, both peaking at 600 ms) latencies. Specifically, N2a amplitudes were more pronounced in response to negative targets compared to neutral ones, whereas LPPa and LPPp amplitudes were higher for negative and positive than for neutral targets. The preferential attention to the emotional content of distracter pictures (i.e., exogenous attention) was reflected in between (N2p at 182 ms). Amplitudes of this component were greater for positive than for neutral distracters. There was no consistent evidence of an interaction effect between the emotional content of targets and distracters. According to these results, valence influenced behavior and early ERP components, while the arousal effect was evident at later neural processing stages. Taken together, these findings indicate that endogenous and exogenous attention seem to develop in a serial manner, suggesting a functional segregation of both attention modalities, at least under the present experimental conditions.

ATTENTION TO CONCURRENT EMOTIONAL TARGETS AND DISTRACTERS RANDOMLY PRESENTED

3.1. Introduction

Evolutionary success depends on the efficiency of the nervous system in processing salient events, namely stimuli related to threat or primary rewards —which perceptively elicit emotional responses, and which have proven themselves to be important in adaptive terms—. Evolution has brought on a variety of physical and cognitive strategies enabling organisms to respond to them appropriately. In this context, the coordination of endogenous and exogenous attentional mechanisms may be understood as an important adaptive tool at the cognitive level. Endogenous attention is consciously directed towards stimuli which the individual has decided to attend (Corbetta & Shulman, 2002; Corbetta et al., 2008; Posner & Petersen, 1990). In contrast, exogenous attention is automatically captured by salient or relevant stimuli (Corbetta & Shulman, 2002; Corbetta et al., 2008; Yantis, 1993), thanks to preattention (i.e., the continuous monitoring of the whole visual scene and the detection of relevant events out of the focus of endogenous attention), and reorientation of attentional resources. These mechanisms are effective even when salient distracters appear while endogenous attention is engaged in another resource-consuming task. Exogenous attention can then be understood as an automatic reorientation of endogenous

attention to the salient distracter. Typically, exogenous attention to the distracter produces disruption in the ongoing task consisting of poorer processing of endogenously attended stimuli (De Focker, Rees, Frith, & Lavie, 2004; Hickey, McDonald, & Theeuwes, 2006). In turn, endogenous attention will tend to ignore distracters in order to avoid overloading of the limited conscious processing resources (Lavie, 2005). As already indicated during the introduction of this Thesis, up to now, endogenous and exogenous attention to emotional stimuli have been explored separately, and evidence on its concurrent course is remarkably scarce.

Studies on *endogenous attention* to emotional pictures have frequently employed passive viewing paradigms or stimulus categorization tasks. At the behavioral level, the emotional content of pictures has been shown to interfere with performance (slower reaction times and/or higher error rates) when it was task-irrelevant (e.g., De Cesare i& Codispoti, 2006; Hajcak & Nieuwenhuis, 2006a; Lichtenstein-Vidne et al., 2012). At the ERP level, studies have found consistent effects in early (N1, P2, N2, EPN; e.g., Carretié et al., 2001a; Codispoti et al., 2007; Cuthbert et al., 2000; Foti et al., 2009; Keil et al., 2001; Schupp et al., 2013) and especially in late ERP components (P3, LPP, PSW; e.g., Carretié et al., 2006; Codispoti et al., 2006; De Cesarei & Codispoti, 2011b; Delplanque et al., 2006; Ferrari et al., 2016; Hajcak & Olvet, 2008; Keil et al., 2002; Olofsson & Polich, 2007; Schupp et al., 2003b), which presented enhanced amplitudes to emotional (negative, positive, or both negative and positive) pictures, regardless of the task employed during the study.

The effect of *exogenous attention* towards emotional distracter pictures has mainly been analyzed through CDTD paradigms. In these tasks, targets (i.e., elements on the screen asked to be endogenously attended by experimental instructions; e.g., centrally-presented digits) and distracters (i.e., other visual elements which are irrelevant to the task; e.g., background pictures) appear at the same time but are physically segregated. When targets are neutral, attentional capture by emotional distracters has been described to produce disruption of the ongoing task, reflected in poorer processing of targets. At the behavioral level, this

capture is observed in increased reaction times and/or error rates in response to targets when distracters are emotional (Buodo et al., 2010; Carretié et al., 2011, 2012; Feng et al., 2012; Keil et al., 2005; MacNamara & Hajcak, 2009; 2010; Müller et al., 2008; 2011; Schönwald & Müller, 2014; Tiferet-Dweck et al., 2016; Vromen et al., 2016). At the neural level, a reliable modulatory effect has been observed in anterior P2, and in the N2 component at anterior and posterior sites. Specifically, these components have shown larger amplitudes in response to emotional (negative, positive, or both negative and positive) than to neutral pictures (Buodo et al., 2010; Carretié et al., 2004; 2011; 2012; Feng et al., 2012; see a review in Carretié, 2014). Additionally, significant modulations have also been observed in EPN, a component concurring with P2 and N2 (De Cesarei et al., 2009; Nordström & Wiens, 2012; Schönwald & Müller, 2014; Wiens & Syrjänen, 2013), and, at late latencies, in the LPP (De Cesarei et al., 2009; Feng et al., 2012; Nordström & Wiens, 2012; Syrjänen & Wiens, 2013; Wiens & Syrjänen, 2013). However, these latter effects have been evident only when distracters were presented at fixation; when distracters were presented at other locations, the effects disappeared (MacNamara & Hajcak, 2009; 2010; Schupp et al., 2013; Wienset al., 2011). Thus, it seems that EPN and LPP more properly index endogenous than exogenous attention (see also MacNamara et al., 2012).

CDTD paradigms are also very suitable for measuring the competition between endogenous and exogenous attention. In this experiment, both targets (endogenously attended), and distracters (task-irrelevant, capturing exogenous attention) were emotionally charged. Studies systematically analyzing the concurrent effect of endogenous and exogenous attention to emotional pictures, which employ this kind of task, are conspicuously scarce. At the behavioral level, on the one hand, there is evidence revealing greater influence of exogenous attention on task performance, as shown by the increase of reaction times and error rates when distracters were negative, compared to neutral ones, regardless of the emotional condition of targets (MacNamara & Hajcak, 2009; 2010). Other results have indicated that emotional targets dominated over distracters, as shown by enhanced behavioral indices in response to negative targets, in comparison

with neutral ones, regardless of the emotional condition of distracters (Lichtenstein-Vidne et al., 2012). Finally, there are also results pointing to an interaction of the emotional content of targets and distracters, where the emotional advantage in response to distracters was only or much more intensely observed when targets were also emotional, i.e., when attentional resources were already engaged in dealing with emotional information (Lichtenstein-Vidne et al., 2012; Vromen et al., 2016).

Electrophysiological evidence on the topic at issue has been collected only in two studies in which negative and neutral pictures were presented both as concurrent targets and distracters, and in which emotional modulation on late latencies was analyzed. Data indicate an advantage of negative targets, compared to neutral ones and regardless the emotional content of distracters, evidenced in larger amplitudes of LPP (MacNamara & Hajcak, 2009; 2010). In addition to these results, an early effect elicited by emotional distracter content is also highly plausible based on previous research addressing exogenous attention (Buodo et al., 2010; Carretié et al., 2004; 2011; 2012; Feng et al., 2012). Further, an interaction of the emotional content of targets and distracters should not be discarded taking into account the results from studies using rapid serial presentation paradigms[4] and stimuli others than scene pictures. Results from the first group of studies have shown that attentional resources allocated to the currently presented picture systematically varied when the preceding picture of the sequence was emotional, but not when it was neutral, a modulation observed at both early (EPN) and late (LPP) stages (Flaisch et al., 2008a; 2008b; Herring et al., 2011). Further, a recent study employing negative and neutral words as targets and negative and neutral faces/bodies as distracters has reported higher amplitudes at early (N1) and late (LPP) latencies, when targets and distracters were incongruent in terms of its emotional charge, compared to the congruent condition (Ma, Liu, & Chen, 2016). Thus, attention to one emotional stimulus may indeed diminish or amplify attention to another emotional stimulus.

[4]In these paradigms, emotional and neutral pictures are presented in a rapid stream with no inter-stimulus interval, so that one stimulus immediately follows the other, and the processing of the first partially overlaps with the processing of the second.

In summary, to the best of our knowledge, there are no neural data directly regarding the competition of endogenous and exogenous attention to emotional scenes, focusing on early stages of processing, which –as explained before– are highly relevant, particularly when attempting to uncover the potential interaction between the endogenous and exogenous modalities. Accordingly, the present study explored this topic through behavioral and electrophysiological indices, administering a CDTD task in which both targets and distracters were emotional (negative, neutral, and positive pictures). As usual in studies carried out in laboratory contexts, valence categories of targets and distracters were randomly combined and presented. At the behavioral level, it was expected that negative targets and negative distracters would be associated with slower reaction times and/or higher error rates, consistent with previous evidence collected from stimulus categorization and CDTD tasks, as reviewed above. A more concrete hypothesis about an advantage of endogenous or exogenous attention or about a potential interaction effect could not be defined, since previous behavioral data are scarce and inconclusive. At the neural level, it was hypothesized, first, that emotional targets would modulate both early and late latencies. Thus, an effect will be manifested in higher amplitudes of early (N1, P2, N2, and/or EPN) as well as late (LPP) components. Based on previous studies, at early stages, negative or positive contents will elicit greater amplitudes, whereas, at late stages, probably both negative and positive pictures, relative to neutral ones, will elicit greater amplitudes. Second, it was also expected that emotional distracters would capture attention, as evidenced by enhanced amplitudes of early ERP components (P2 and/or N2) for emotional (negative or positive) compared to neutral distracters. Previous data do not allow hypothesizing on whether effects related to both attentional modalities will occur serially or in parallel. In the latter case, the same early ERP component would be modulated by both target and distracter contents, showing some type of additive or interactive pattern.

3.2. Objectives and hypotheses

Accordingly, Experiment 1 met the following objectives of the present Thesis (see Section 2):

1. To explore how the competition between endogenous and exogenous attention is reflected at the behavioral level, and whether there is any advantage of one modality over the other and/or any interaction effect.
2. To disentangle the neural time course of the competing attention effects, and to determine whether both responses are reflected in the ERP in a parallel manner or in a serial order.
3. To analyze how valence and arousal of stimuli modulate the exogenous-endogenous competition.

These objectives were associated with the following hypotheses (Section 2):

1. Increased reaction times and/or error rates will be observed in response to negative targets and to negative distracters, compared to neutral ones.
2. Emotional targets will yield higher amplitudes than neutral ones at both early (N1, P2, N2, and/or EPN) and late latencies (LPP); emotional distracters, in comparison with neutral ones, will produce enhanced amplitudes only in early components (P2 and/or N2).
3. Valence will modulate ERPs at early latencies (N1, P2, N2, and/or EPN), whereas arousal effects will appear at late latencies (LPP).

3.3. Methods

3.3.1. Participants

Thirty-six students from the Universidad Autónoma de Madrid participated in Experiment 1, although only data from 31 were finally analyzed, as explained later. Ages of these 31 participants (25 women) ranged from 18 to 25 (mean = 19.8, standard deviation = 1.6). All of them participated voluntarily after providing

informed consent according to the Declaration of Helsinki, and received course credit for their participation. They reported normal or corrected to normal visual acuity. The study was approved by the Research Ethics Committee of the Universidad Autónoma de Madrid.

3.3.2. Stimuli and Procedure

Participants were placed in an electrically shielded, sound-attenuated and video-monitored room, at a distance of approximately 70 cm from the screen. Stimuli were presented on a ViewPixx screen using Psychtoolbox 3 task programming extensions for Matlab (Brainard, 1997; Kleiner, Brainard & Pelli, 2007). As shown in Figure 1, each trial was composed of two identical negative, neutral, or positive pictures (relevant for the primary task) flanking a fixation cross in the center of the screen; in half of the trials, the two pictures were presented in mirror orientation to each other. Additionally, in the background of each stimulus appeared a negative, neutral, or positive distracter image (irrelevant for the primary task). Thus, trials were of nine different types: Target (Negative, Neutral, Positive) × Distracter (Negative, Neutral, Positive). Visual angle of the whole stimulus was 41.1° (width) × 23.8° (height), and size of the two target images together was 11.4° (width) × 4.7° (height). All stimuli were displayed on the screen for 350 ms, followed by a white fixation cross on a black screen (2650 ms), so that the resulting stimulus onset asynchrony was 3000 ms. Participants were asked to look continuously at the center of the screen, to press —as accurately and rapidly as possible— one key if both target images were shown in mirror orientation, and a different key if they were not, and to refrain from blinking during stimulus presentation to minimize ocular interference. Furthermore, before starting the experiment, they completed a practice block of ten trials (five target pictures presented in mirror orientation) to ensure they understood the task instructions. There were 40 trials of each combination of Target × Distracter levels (half of them showing targets in mirror), consisting of 20 different negative, 20 neutral, and 20 positive target and distracter pictures, each of them presented two times. The total

number of 360 trials was displayed randomly in three runs of 120, separated by a rest period.

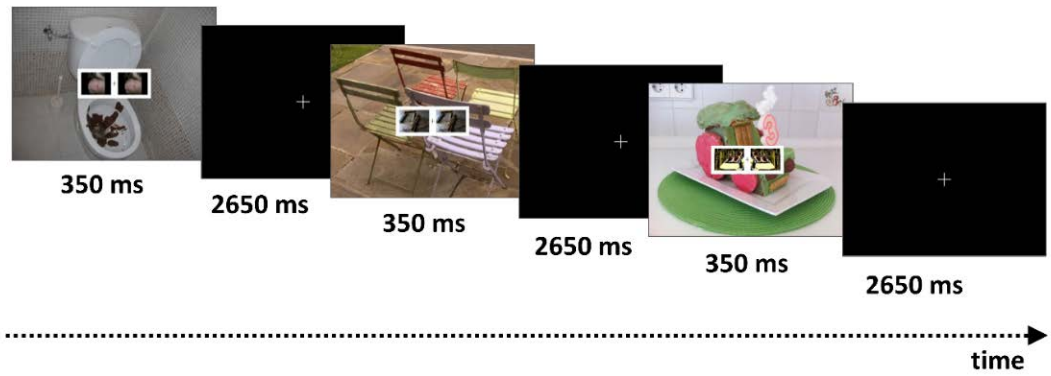


Figure 1. Schematic illustration of the task. Please note that some of these example pictures were not among the experimental stimuli.

All pictures were taken from the EmoMadrid database (www.uam.es/CEACO/EmoMadrid.htm) according to valence and arousal average normative ratings available from this database. Two groups of 60 pictures[5] were selected (20 of each emotional category); pictures of one group were presented as targets, and pictures of the other group as distracters. These 20 pictures of each stimulus group and emotional category were combined into 180 final stimuli (20 negative targets superposed on 20 negative, 20 neutral, and 20 positive distracters, etc.). Picture categories included disgusting scenes, weapons, people suffering or in threatening situations, injuries, and threatening animals as negative stimuli; household and other objects, furniture, and scenes showing people in non-significant situations as

[5] TARGETS:
negative: EM139, EM155, EM245, EM293, EM320, EM321, EM348, EM361, EM396, EM405, EM418, EM420, EM486, EM569, EM571, EM573, EM586, EM596, EM598, EM631.
neutral: EM014, EM026, EM051, EM116, EM132, EM135, EM158, EM192, EM198, EM203, EM206, EM328, EM329, EM335, EM351, EM498, EM509, EM628, EM676, EM677.
positive: EM003, EM046, EM146, EM186, EM190, EM232, EM234, EM279, EM384, EM387, EM417, EM421, EM428, EM438, EM445, EM453, EM457, EM458, EM465, EM473.

DISTRACTERS:
negative: EM031, EM223, EM281, EM284, EM327, EM354, EM367, EM380, EM390, EM419, EM562, EM564, EM578, EM597, EM605, EM608, EM609, EM613, EM619, EM620.
neutral: EM053, EM083, EM105, EM133, EM244, EM248, EM250, EM254, EM333, EM336, EM338, EM446, EM500, EM506, EM510, EM540, EM552, EM644, EM674, EM680.
positive: EM118, EM185, EM199, EM231, EM236, EM240, EM358, EM369, EM372, EM386, EM388, EM412, EM422, EM424, EM427, EM436, EM449, EM456, EM462, EM528.

neutral stimuli; and erotic scenes, exciting sports, food, and people having fun as positive stimuli. Each of the three categories contained images of people to the same extent, in order to control for potential effects driven by the presence of faces. Two-way repeated-measures analyses of variance (ANOVAs), using Stimulus (Target, Distracter) × Emotion (Negative, Neutral, Positive) as factors, were computed on picture properties (see Table 1), in order to confirm that 1) valence equally differed from negative to neutral and from neutral to positive (i.e., negative-neutral-positive valence averages depicting a linear ascending slope); 2) arousal was similar for negative and positive stimuli, but higher for these emotional categories than for neutral stimuli (i.e., negative-neutral-positive arousal averages depicting a "V"); 3) valence and arousal scores were balanced for each emotional category between the two groups of target and distracter pictures; 4) there were no significant differences between pictures regarding luminosity and spectral density in eight frequency bands (768-384, 384-192, 192-96, 96-48, 48-24, 24-12, 12-6, 6-3 cycles/image, and residual). Means are included in Table 1a and *F* and *p* values of the contrasts in Table 1b. As expected, all results were non-significant [$p > 0.05$], except for the Valence and Arousal dimensions. Specifically, Bonferroni corrected post-hoc tests indicated that Negative and Positive pictures showed different Valence [$p < 0.001$] but not different Arousal levels [$p > 0.05$], and that they differed from Neutral pictures in both dimensions [all $p < 0.001$]. In addition to the normative ratings, participants' assessments of Valence and Arousal were measured as well. Thus, at the end of the recording session, participants themselves filled out a bidimensional scale for each picture, providing their own ratings on valence and arousal. Results are reported in Table 1 and in the Results section.

3.3.3. Recording and pre-processing

Electroencephalographic (EEG) activity was recorded using an electrode cap (ElectroCap International) with tin electrodes. Fifty-nine electrodes were placed at the scalp following the distribution of the International 10-20 System. All scalp electrodes were referenced to the nose tip. Electrooculographic (EOG) data were

recorded supra- and infra-orbitally (vertical EOG) as well as from the left versus right orbital rim (horizontal EOG). An online analog bandpass filter of 0.3 Hz to 10 kHz was applied. Recordings were continuously digitized at a sampling rate of 420Hz. The continuous recording was divided into 1000 ms epochs for each trial, beginning 200 ms before stimulus onset. Behavioral activity was recorded through a numeric keypad. Outlier trials (with responses before 200 ms or after 2000 ms), incorrect trials, and trials with no response were eliminated. An offline digital bandpass filter of 0.3 to 20 Hz was applied using Fieldtrip software (Oostenveld, Fries, Maris, & Schoffelen, 2011).

Ocular artifact removal was carried out through an Independent Component Analysis based strategy (Jung et al., 2000) as implemented in Fieldtrip. After this process, a second stage of visual inspection of EEG data was conducted. If any further artifact was present, the corresponding trial was discarded. The average number of trials accepted within each stimulus category after this rejection of artifacts and incorrect responses is included in Table 3a. A minimum criterion of 20 correct and artifact-free trials per condition and participant was set to ensure a reasonable signal-to-noise ratio of the ERP averages. Data from five participants could not be analyzed because of non-solvable anomalies in the recordings of several EEG leads (N=2), strong eye-movements (N=2), and behavioral responses non-different from chance (N=1).

3.3.4. Data analysis

In all ANOVAs described below, post-hoc comparisons were performed to determine the significance of pairwise contrasts using the Bonferroni correction procedure. In order to break down interaction terms, simple effects analyses were conducted (i.e., comparisons of the effects of one independent variable between the levels of the other; e.g., Field, 2013). Effect sizes were computed using the partial eta-square (η^2_p) method. The analyses were carried out using SPSS 19.0 software package (IBM SPSS, 2010).

Table 1. (a) Means and standard deviations (in parenthesis) of picture properties and ratings. i) Normative ratings from EmoMadrid. ii) Individual ratings of participants. (b) ANOVA results of picture properties and ratings. i) Normative ratings from EmoMadrid. ii) Individual ratings of participants.

(a)	**Target**			**Distracter**		
	Negative	**Neutral**	**Positive**	**Negative**	**Neutral**	**Positive**
Normative ratings of pictures						
Valence (-2=negative to 2=positive)	-1.35	0.04	1.30	-1.32	0.02	1.31
	(0.26)	(0.12)	(0.17)	(0.24)	(0.15)	(0.17)
Arousal (-2=negative to 2=positive)	1.16	0.02	1.09	1.21	-0.01	1.15
	(0.31)	(0.21)	(0.34)	(0.35)	(0.22)	(0.37)
SF768 - SF384 (cycles/image)	190	241	260	220	290	271
	(169)	(199)	(213)	(201)	(318)	(299)
SF384 - SF192 (cycles/image)	1353	1461	1738	1718	1744	1632
	(1197)	(908)	(1081)	(1642)	(1381)	(1339)
SF192 - SF96 (cycles/image)	7651	8092	10302	9676	9889	9244
	(5867)	(5215)	(6197)	(8815)	(6723)	(5118)
SF96 - SF48 (cycles/image)	44124	45610	65609	55188	56041	51456
	(31171)	(29444)	(42043)	(42691)	(40618)	(25455)
SF48 - SF24 (cycles/image)	253506	280980	363766	310560	314272	300154
	(165072)	(167980	(249102)	(242743)	(226113)	(147553)
SF24 - SF12 (cycles/image)	1466452	1568557	1908202	1592904	1683918	1697220
	(841579)	(857754)	(1233626)	(1256792)	(1406461)	(819247)
SF12 - SF6 (cycles/image)	7660899	10397824	11448164	8545971	7332244	10288867
	(3018589)	(11133429)	(10270250)	(6835323)	(4603392)	(8243743)
SF6 - SF3 (cycles/image)	41453815	46294310	39920441	65329112	43496598	43551767
	(28468050)	(38748956)	(22717947)	(67432978)	(81900302)	(31926778)
Residual SF (cycles/image)	1018539243	932680896	1039896361	1004174536	1103634918	1072660699
	(584287950)	(399152459)	(432809692)	(560038119)	(577796910)	(632321804)
Luminosity (0=black to 255=white)	112	108	116	112	120	117
	(38)	(28)	(25)	(36)	(35)	(43)
Subjective ratings of pictures						
Valence (1=negative to 5=positive)	2.05	3.10	4.13	1.96	3.05	4.18
	(0.33)	(0.12)	(0.40)	(0.36)	(0.19)	(0.43)
Arousal (1=negative to 5=positive)	3.83	2.95	3.84	3.98	2.93	3.87
	(0.34)	(0.20)	(0.49)	(0.41)	(0.24)	(0.56)

(b)	*F*	*df*	*p*	*ηp²*
Valence				
Target-Distracter	0.0	1,30	0.917	0.001
Emotion	2628.2	2,60	< 0.001***	0.993
neg - neu			< 0.001***	
neg - pos			< 0.001***	
neu - pos			< 0.001***	
Emotion × Target-Distracter	0.3	2,60	0.752	0.015
Arousal				
Target-Distracter	0.2	1,30	0.644	0.011
Emotion	176.8	2,60	< 0.001***	0.903
neg - neu			< 0.001***	
neg - pos			1.000	
neu - pos			< 0.001***	
Emotion × Target-Distracter	0.3	2,60	0.761	0.014
SF768 - SF384				
Target-Distracter	0.4	1,19	0.544	0.020
Emotion	0.8	2,38	0.466	0.039
Emotion × Target-Distracter	0.1	2,38	0.936	0.003
SF384 - SF192				
Target-Distracter	0.4	1,19	0.533	0.021
Emotion	0.1	2,38	0.877	0.007
Emotion × Target-Distracter	0.5	2,38	0.644	0.023
SF192 - SF96				
Target-Distracter	0.4	1,19	0.528	0.021
Emotion	0.3	2,38	0.724	0.017
Emotion × Target-Distracter	0.8	2,38	0.462	0.040
SF96 - SF48				
Target-Distracter	0.1	1,19	0.743	0.006
Emotion	0.7	2,38	0.481	0.038
Emotion × Target-Distracter	1.8	2,38	0.186	0.085
SF48 - SF24				
Target-Distracter	0.1	1,19	0.810	0.003
Emotion	0.7	2,38	0.501	0.036
Emotion × Target-Distracter	0.9	2,38	0.397	0.047
SF24 - SF12				
Target-Distracter	0.0	1,19	0.959	0.000
Emotion	0.7	2,38	0.522	0.034
Emotion × Target-Distracter	0.3	2,38	0.744	0.744
SF12 - SF6				
Target-Distracter	1.1	1,19	0.306	0.055
Emotion	1.5	2,38	0.242	0.072
Emotion × Target-Distracter	0.5	2,38	0.606	0.026
SF6 - SF3				
Target-Distracter	1.0	1,19	0.330	0.050
Emotion	0.5	2,38	0.601	0.026
Emotion × Target-Distracter	0.7	2,38	0.503	0.036
Residual SF				
Target-Distracter	0.7	1,19	0.428	0.033
Emotion	0.1	2,38	0.896	0.006
Emotion × Target-Distracter	0.3	2,38	0.760	0.014
Luminosity				
Target-Distracter	0.8	1,19	0.381	0.041
Emotion	0.2	2,38	0.817	0.011
Emotion × Target-Distracter	0.3	2,38	0.742	0.016

3.3.4.1. Assessment of pictures

Two-way repeated-measures ANOVAs were computed on participants' assessments of valence and arousal of pictures, using Stimulus (Target, Distracter) × Emotion (Negative, Neutral, Positive) as factors.

3.3.4.2. Behavioral data

Reaction times (in milliseconds) and error rates (ranging from 0 to 1) were submitted to two-way repeated 3×3 ANOVAs introducing Target (Negative, Neutral, Positive) and Distracter (Negative, Neutral, Positive) as factors. Outliers were omitted in all analyses. Means and standard deviations of behavioral data are presented in Table 2a.

3.3.4.3. ERP data

a) Detection, spatio-temporal characterization, and quantification of relevant ERP components

In order to detect and quantify the ERP components taken into account in hypothesis 2, two-step covariance-matrix-based principal component analysis (PCA) was employed (e.g., Chapman & McCrary, 1995; Chapman, Hoag, & Giaschi, 2004; Dien, 2010; 2012; Dien, Beal, & Berg, 2005; Dien, Khoe, & Mangun, 2007). As explained in the Introduction, PCA has been repeatedly recommended to differentiate individual ERP components and to handle component overlap. This technique defines temporal windows and spatial regions mathematically, based on the covariance of amplitudes both in time and in space, avoiding subjectivity or inter-judge discrepancies often characterizing the traditional window and region definition based on manual or visual criteria. Thus, it guarantees more objective and reliable results than traditional, visual inspection-based methods.

Temporal PCA (tPCA) computes the covariance between ERP time points, which tends to be high between those involved in the same component and low between those belonging to different components. The solution is therefore a set of

nearly independent factors made up of highly covarying time points, which ideally correspond to ERP components. Extracted temporal factors (TF) are quantified in factor loadings and factor scores, which are linearly related to amplitudes: original amplitudes are a joint function of factor loadings and factor scores multiplied together (Dien, Tucker, Potts, & Hartry-Speiser, 1997; Dien et al., 2005, 2007). The decision on the number of factors to select was based on the scree test (Cliff, 1987). Extracted factors were submitted to promax rotation (Dien, 2010; 2012; Dien et al., 2005, 2007).

Once quantified in temporal terms, and prior to statistical contrasts on experimental effects, temporal factor scores were submitted to spatial PCA (sPCA) in order to decompose topographies at the scalp level into their main spatial regions. Thus, while tPCA separates ERP components along time, sPCA reliably separates them in space, each region or spatial factor (SF) ideally reflecting one of the concurrent neural processes underlying each temporal factor. This spatial decomposition is an advisable strategy prior to statistical contrasts, given that ERP components may behave differently in some scalp areas than in others (e.g., they may present opposite polarity or react heterogeneously to experimental manipulations). Basically, each spatial factor is formed by the scalp points where recordings tend to covary. So, the shape of the sPCA-configured regions is functionally based. Moreover, each spatial factor can also be quantified through the spatial factor score, a single parameter that reflects the amplitude of the whole spatial factor. Similarly, the decision on the number of factors to select was based on the scree test, and extracted factors were submitted to promax rotation as well. Statistical analyses were computed on factor scores which are linearly related to amplitudes, as explained above.

b) Scalp ERP analyses

Two-way repeated-measures 3×3 ANOVAs on spatial factor scores were carried out on the temporal factors corresponding to the components which were relevant to hypothesis 2, with respect to Target (Negative, Neutral, Positive) and Distracter (Negative, Neutral, Positive).

3.4. Results

3.4.1. Assessment of pictures

ANOVAs computed on participants' ratings on Valence and Arousal confirmed, first, that stimulus Valence was as assumed a priori, second, that Negative and Positive pictures were balanced with respect to their Arousal levels, and third, that there were no differences between Targets and Distracters. Specifically, results showed significant differences between emotional categories in both dimensions [Valence: $F(2,60) = 369.7$, GG corrected $p < 0.001$, $\eta^2_p = 0.925$; Arousal: $F(2,60) = 103.3$, $p < 0.001$, $\eta^2_p = 0.775$]. Additionally, Bonferroni corrected post-hoc contrasts indicated that Negative and Positive pictures showed different Valence [$p < 0.001$] but not different Arousal levels [$p > 0.05$], and that they differed from Neutral pictures in both dimensions [all $p < 0.001$]. There were no differences between Target and Distracter pictures [Valence: $F(1,30) = 0.5$, $p > 0.05$; Arousal: $F(1,30) = 1.0$, $p > 0.05$]. Results are included in Table 1b.

3.4.2. Behavioral data

Given that reaction times lacked normal distribution, a data transformation was applied to the original values in order to achieve normality. Thus, data were transformed as 1/[reaction times], as recommended for this kind of distribution (Tabachnick & Fidell, 2001). Statistical analyses were then performed on these normally transformed data, though Table 2a includes the original ones for facilitating interpretation. Both behavioral indices were submitted to two-way repeated 3×3 ANOVAs introducing Target (Negative, Neutral, Positive) and Distracter (Negative, Neutral, Positive) as factors.

Results are shown in Figure 2 and in Table 2b; they indicated a significant main effect on error rates for Target [$F(2,60) = 34.2$, $p < 0.001$, $\eta^2_p = 0.532$], but not for Distracter, nor for the interaction of Target × Distracter [both $p > 0.05$]. Bonferroni corrected post-hoc tests indicated that significantly higher error rates were associated with Negative Targets, compared to Neutral and Positive ones [both $p < 0.001$].

Moreover, ANOVAs showed a significant interaction of Target × Distracter for reaction times [$F(4,120) = 3.0$, $p = 0.020$, $\eta^2_p = 0.092$]. Specifically, reaction times in response to Positive Targets, and marginally to Negative ones, were faster than to Neutral ones, only when Distracters were Negative [$p = 0.001$, and $p = 0.094$, respectively], as shown by Bonferroni corrected pairwise comparisons. Further, comparing Positive Targets to Neutral ones within Distracter levels, the interaction effect was confirmed; the difference between Positive and Neutral Targets varied significantly from one Distracter level to the other, being significant when Distracters were Negative (compared to Neutral) [$F(1,30) = 7.9$, $p = 0.009$, $\eta^2_p = 0.208$], and non-significant when they were Positive (compared to neutral) [$F(1,30) = 0.6$, $p = 0.437$, $\eta^2_p = 0.020$]. Additionally, the same pattern was observed for Negative compared to Neutral Targets, where reaction times to Negative Targets were also faster than to Neutral ones when the Distracter was Negative (compared to Neutral) [$F(1,30) = 4.3$, $p = 0.047$, $\eta^2_p = 0.125$], but not when it was Positive (compared to Neutral) [$F(1,30) = 0.3$, $p = 0.602$, $\eta^2_p = 0.009$].

3.4.3. ERP data

a) <u>Detection, spatio-temporal characterization, and quantification of relevant ERP components</u>

Figure 3a and Figure 4 show grand averages after subtracting the baseline activity (200 ms of prestimulus recording) from each ERP. As explained above, in order to detect and quantify outstanding ERP components, a tPCA was applied. As a consequence, 11 temporal factors were extracted from the ERP, as shown in Figure 3b. sPCAs subsequently applied to these temporal factor scores extracted two spatial factors for each temporal factor, one anterior or fronto-central (which will be labeled with the letter “a”), and one posterior or parieto-occipital (which will be labeled “p”).

Among the 11 temporal factors, six were relevant to hypothesis 2 of this study. Table 3a presents mean factor scores and standard deviations of the six components at all corresponding scalp regions. As may be observed in Figure 3, in

chronological order, the first temporal factor was TF 6 (peaking at 97 ms), a negative component at anterior and posterior scalp regions, which was defined as N1a and N1p, depending on its location. The second was TF 7 (peaking at 140 ms), a relative negativity at frontal areas, and a positive waveform at posterior sites. Therefore, this component corresponds to N2a at fronto-central electrodes and to P1p at parieto-occipital electrodes.

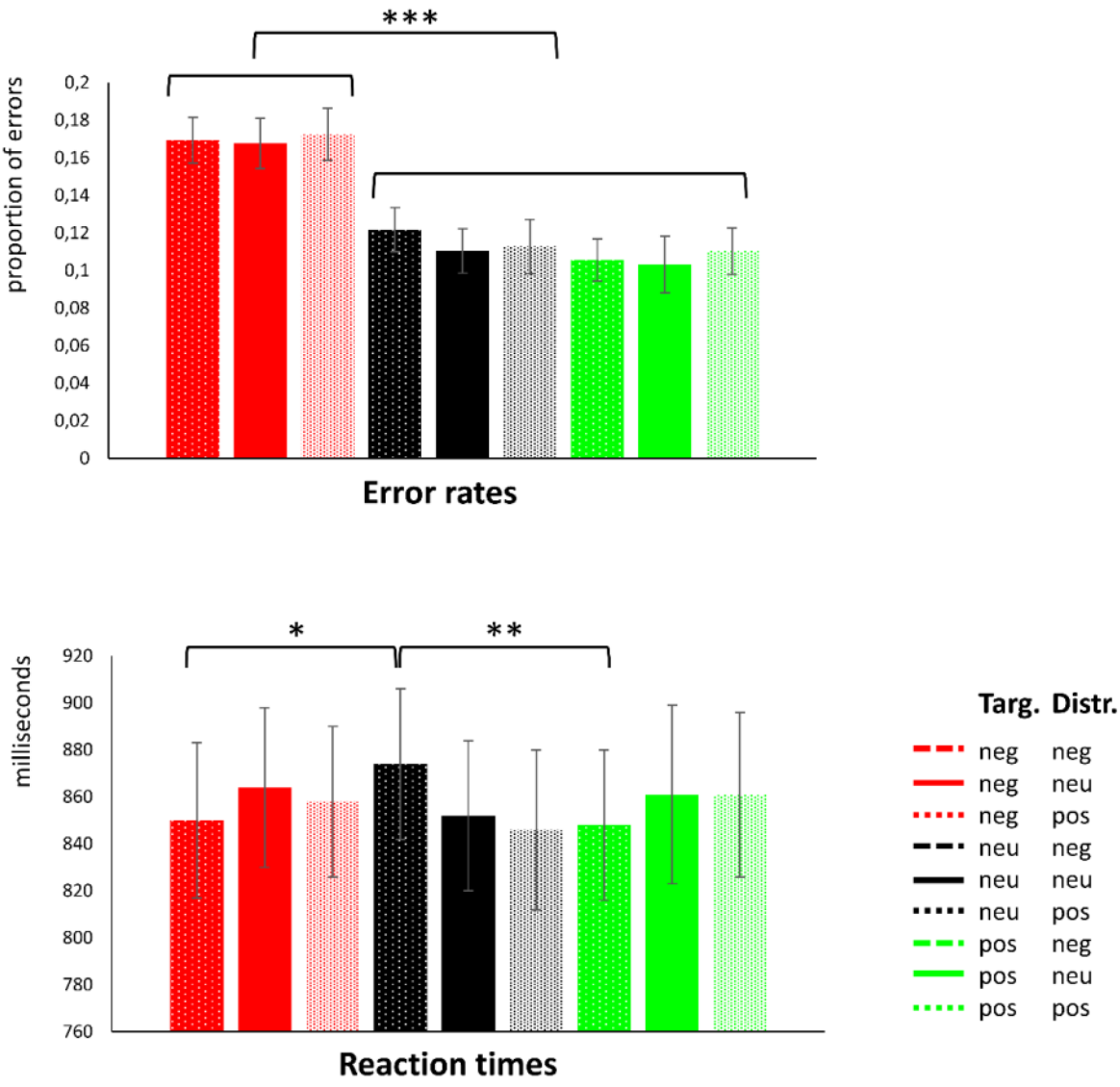


Figure 2: Behavioral results.

Table 2. (a) Means and standard deviations (in parenthesis) of behavioral data. (b) ANOVA results of behavioral data.

(a)	Neg distracter			Neu distracter			Pos distracter		
	Neg target	Neu target	Pos target	Neg target	Neu target	Pos target	Neg target	Neu target	Pos target
Behavior									
Reaction times (ms)	849	874	848	864	852	861	859	846	861
	(181)	(185)	(179)	(189)	(175)	(210)	(176)	(188)	(196)
Error rates (%)	16.9	12.2	10.6	16.8	11.0	10.3	17.3	11.3	11.0
	(6.8)	(7.3)	(6.2)	(7.4)	(6.6)	(8.3)	(7.8)	(8.0)	(6.9)

(b)	*F*	*df*	*p*	ηp^2
Reaction times				
Target	0.2	2,60	0.850	0.005
Distracter	0.3	2,60	0.733	0.010
Target × Distracter	3.0	4,120	0.020*	0.092
Neg distr: Target: neg - neu			0.094	
Neg distr: Target: neg - pos			1.000	
Neg distr: Target: neu - pos			0.001**	
Error rates				
Target	34.2	2,60	< 0.001***	0.532
neg - neu			< 0.001***	
neg - pos			< 0.001***	
neu - pos			0.672	
Distracter	0.5	2,60	0.638	0.015
Target × Distracter	0.2	4,120	0.931	0.007

The third relevant component was TF 5 which, with the peak at 182 ms, was associated with a positive wave at anterior sites (P2a) sharing latencies with a negative one at posterior regions (N2p). The fourth was TF 9, a positive parieto-occipital component peaking at 239 ms and corresponding to P2p. The fifth factor was TF 1 with its peak at 346 ms, a parieto-occipital positivity which will be denominated P3p hereafter. Finally, the last one was TF 2, a late positivity observed at anterior and posterior scalp regions and peaking at 600 ms, which matches with LPPa and LPPp. These labels will be employed from now on to make results easier to understand. See Figure 4 for the correspondence of labels and ERP components and Table 3b for further information on spatial regions.

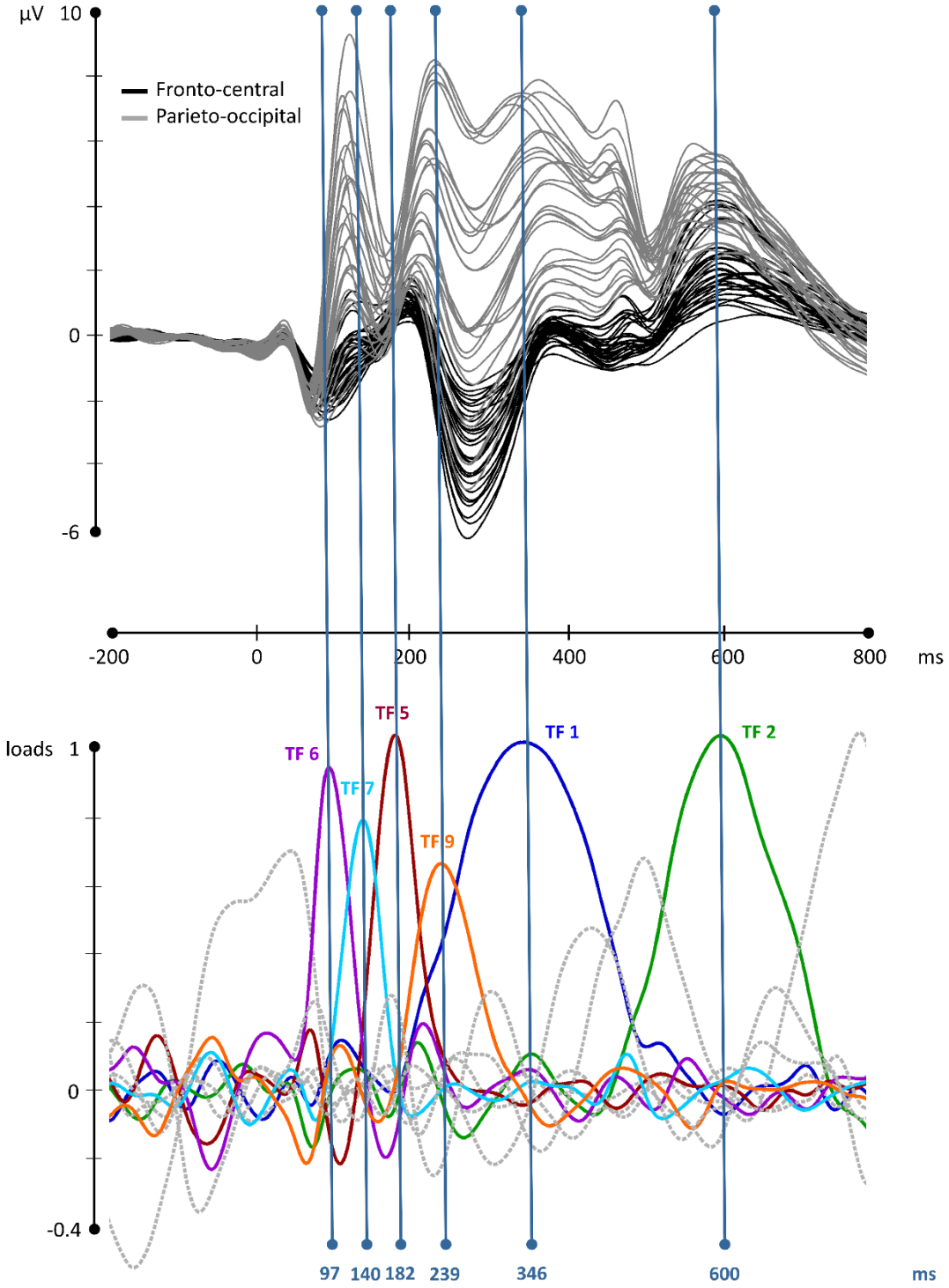


Figure 3. (a) Grand averages across all conditions at 59 sites. Fronto-central electrodes are drawn in black and parieto-occipital electrodes in gray. (b) tPCA factor loadings after promax rotation. Relevant temporal factors are highlighted in color. Blue vertical lines indicate the correspondence of temporal factors and ERP components at anterior and posterior scalp regions.

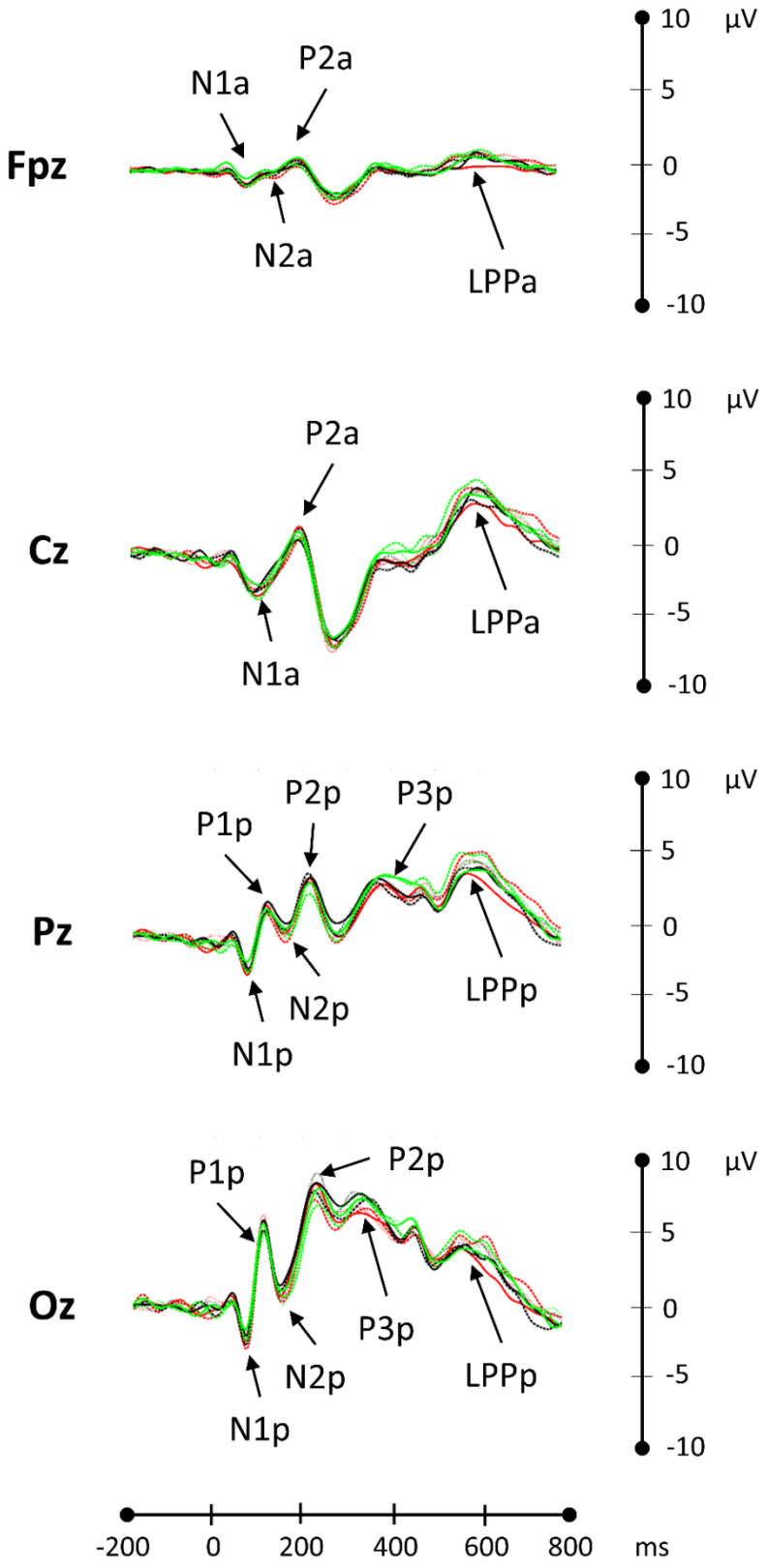


Figure 4. Grand averages at selected midline electrodes signaling all relevant components extracted through PCA.

b) Experimental effects on scalp ERP components

Accordingly, for each of the six temporal factors, ANOVAs on Target (Negative, Neutral, Positive) × Distracter (Negative, Neutral, Positive) were computed for the anterior and posterior spatial factors, if relevant (please note that FT 1 and FT 9 did not correspond to any anterior component, so ANOVAs were applied only on the posterior region). As previously indicated, factor scores are directly related to amplitudes. Results are summarized in Table 3b, where *F*-ratios and corresponding *p* values of all contrasts can be found. All results are also illustrated in Figure 5.

i. N1a (97 ms)

ANOVAs on N1a did not yield any significant main or interaction effects.

N1p (97 ms)

There were no significant results either.

ii. N2a (140 ms)

Results of N2a (fronto-central N2) indicated a significant main effect of Target [$F(2,60) = 4.8$, $p = 0.012$, $\eta^2_p = 0.138$], where amplitudes were more negative in response to Negative, than to Neutral and marginally to Positive attended pictures, as indicated by Bonferroni pairwise tests [$p = 0.016$, and $p = 0.061$, respectively]. The effect is shown in Figure 5 (1). There were no more significant main or interaction effects.

P1p (140 ms)

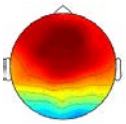
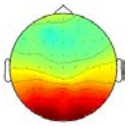
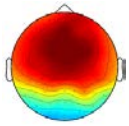
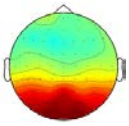
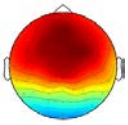
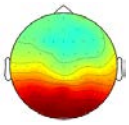
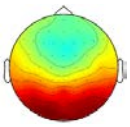
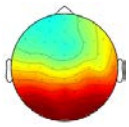
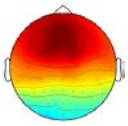
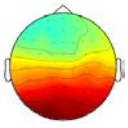
P1 at parieto-occipital sites did not show any significant main or interaction effects.

iii. N2p (182 ms)

ANOVAs on N2p manifested a significant main effect of Distracter at parieto-occipital areas where the polarity of the component appears negative [$F(2,60) = 5.2$, $p = 0.008$, $\eta^2_p = 0.147$]. Post-hoc tests showed that Positive Distracters elicited significantly more negative ERP amplitudes than Neutral ones [$p = 0.017$], as illustrated in Figure 5 (2). No more significant effects were observed.

Table 3. (a) Neural data. i) Average number of valid trials. ii) Means and standard deviations (in parenthesis) of neural data. (b) ANOVA results of neural data. Topographical plots represent sPCA factor loadings after promax rotation; please note that, even if the component appears as a negative peak in the grand average, loadings are always positive.

(a)	**Neg distracter**			**Neu distracter**			**Pos distracter**		
	Neg target	**Neu target**	**Pos target**	**Neg target**	**Neu target**	**Pos target**	**Neg target**	**Neu target**	**Pos target**
Trials									
Average nº of trials	28.7	30.1	30.8	28.9	30.6	31.2	28.3	31.1	30.8
	(5.7)	(5.8)	(5.3)	(5.4)	(5.0)	(5.0)	(5.7)	(4.7)	(4.7)
Scalp level ERPs									
N1a (factor scores)	-0.012	0.053	0.155	0.071	-0.049	-0.027	-0.173	0.247	-0.265
	(-1.077)	(1.044)	(1.191)	(0.944)	(1.000)	(0.848)	(1.061)	(0.957)	(0.858)
N1p (factor scores)	-0.088	0.109	0.294	0.009	0.033	-0.037	-0.190	0.119	-0.250
	(0.928)	(1.057)	(1.100)	(0.828)	(1.134)	(0.861)	(1.038)	(1.090)	(0.928)
N2a (factor scores)	-0.205	-0.195	0.032	-0.113	0.375	0.019	-0.070	0.106	0.051
	(0.921)	(1.010)	(1.011)	(1.034)	(1.079)	(0.964)	(1.094)	(1.009)	(0.851)
P1p (factor scores)	-0.084	-0.072	-0.031	-0.068	0.199	-0.119	0.065	0.040	0.071
	(1.122)	(0.770)	(1.009)	(0.826)	(1.064)	(0.967)	(1.117)	(1.149)	(0.992)
P2a (factor scores)	-0.150	0.148	-0.081	0.134	-0.134	-0.003	-0.051	0.252	-0.114
	(1.189)	(0.901)	(1.176)	(0.935)	(0.993)	(1.008)	(0.922)	(0.853)	(1.012)
N2p (factor scores)	-0.156	0.097	0.005	0.190	0.116	0.092	-0.194	0.046	-0.196
	(1.042)	(0.940)	(1.047)	(0.928)	(1.175)	(1.016)	(0.912)	(0.872)	(1.074)
P2p (factor scores)	0.041	0.004	-0.002	-0.071	0.167	0.078	-0.268	0.040	0.011
	(1.097)	(1.014)	(0.872)	(0.866)	(1.086)	(0.925)	(1.130)	(0.952)	(1.085)
P3p (factor scores)	-0.129	-0.081	-0.090	-0.018	0.045	0.077	0.057	0.065	0.075
	(1.213)	(0.870)	(1.173)	(0.943)	(0.950)	(0.947)	(1.059)	(0.967)	(0.922)
LPPa (factor scores)	0.143	-0.312	0.032	-0.072	-0.049	0.042	0.180	-0.023	0.059
	(0.967)	(0.949)	(1.050)	(1.172)	(0.890)	(1.027)	(0.975)	(0.898)	(1.083)
LPPp (factor scores)	0.265	-0.321	0.044	-0.052	-0.110	0.032	0.182	-0.122	0.083
	(1.009)	(1.004)	(1.058)	(0.967)	(0.971)	(1.069)	(1.012)	(0.873)	(1.025)

(b)	*TF*	*SF*		*F*	*df*	*p*	ηp^2
			**N1a**				
			Target	0.8	2,60	0.447	0.026
			Distracter	0.7	2,60	0.483	0.024
			Target × Distracter	1797	4,120	0.134	0.057
	6		**N1p**				
			Target	1.8	2,60	0.174	0.057
			Distracter	2.6	2,60	0.082	0.080
			Target × Distracter	1.7	4,120	0.163	0.052
			**N2a**				
			Target	4.8	2,60	0.012*	0.138
			neg - neu			0.016*	
			neg - pos			0.061	
			neu - pos			1.000	
	7		Distracter	2.3	2,60	0.109	0.071
			Target × Distracter	1.5	4,120	0.198	0.049
			**P1p**				
			Target	1.1	2,60	0.331	0.036
			Distracter	1.3	2,60	0.269	0.043
			Target × Distracter	1.1	4,120	0.370	0.035
			**P2a**				
			Target	1.2	2,60	0.318	0.037
			Distracter	0.2	2,60	0.845	0.006
			Target × Distracter	2.1	4,120	0.088	0.065
			Neu targ: Distr: neg - neu			0.278	
			Neu targ: Distr: neg - pos			1.000	
			Neu targ: Distr: neu - pos			0.054	
	5		**N2p**				
			Target	1.8	2,60	0.173	0.057
			Distracter	5.2	2,60	0.008**	0.147
			neg - neu			0.116	
			neg - pos			0.696	
			neu - pos			0.017*	
			Target × Distracter	1.2	4,120	0.309	0.039
			**P2p**				
			Target	2.1	2,60	0.137	0.064
	9		Distracter	1.3	2,60	0.268	0.043
			Target × Distracter	1.4	4,120	0.241	0.044
			**P3p**				
			Target	0.2	2,60	0.790	0.008
			Distracter	4.1	2,60	0.022*	0.120
	1		neg - neu			0.173	
			neg - pos			0.014*	
			neu - pos			1.000	
			Target × Distracter	0.1	4,120	0.989	0.003
			**LPPa**				
			Target	5.1	2,60	0.009**	0.145
			neg - neu			0.003**	
			neg - pos			1.000	
			neu - pos			0.081	
			Distracter	1.1	2,60	0.331	0.036
			Target × Distracter	1.6	4,120	0.167	0.052
	2		**LPPp**				
			Target	7.9	2,60	0.001**	0.207
			neg - neu			< 0.001***	
			neg - pos			1.000	
			neu - pos			0.027*	
			Distracter	0.6	2,60	0.546	0.020
			Target × Distracter	1.5	4,120	0.225	0.049

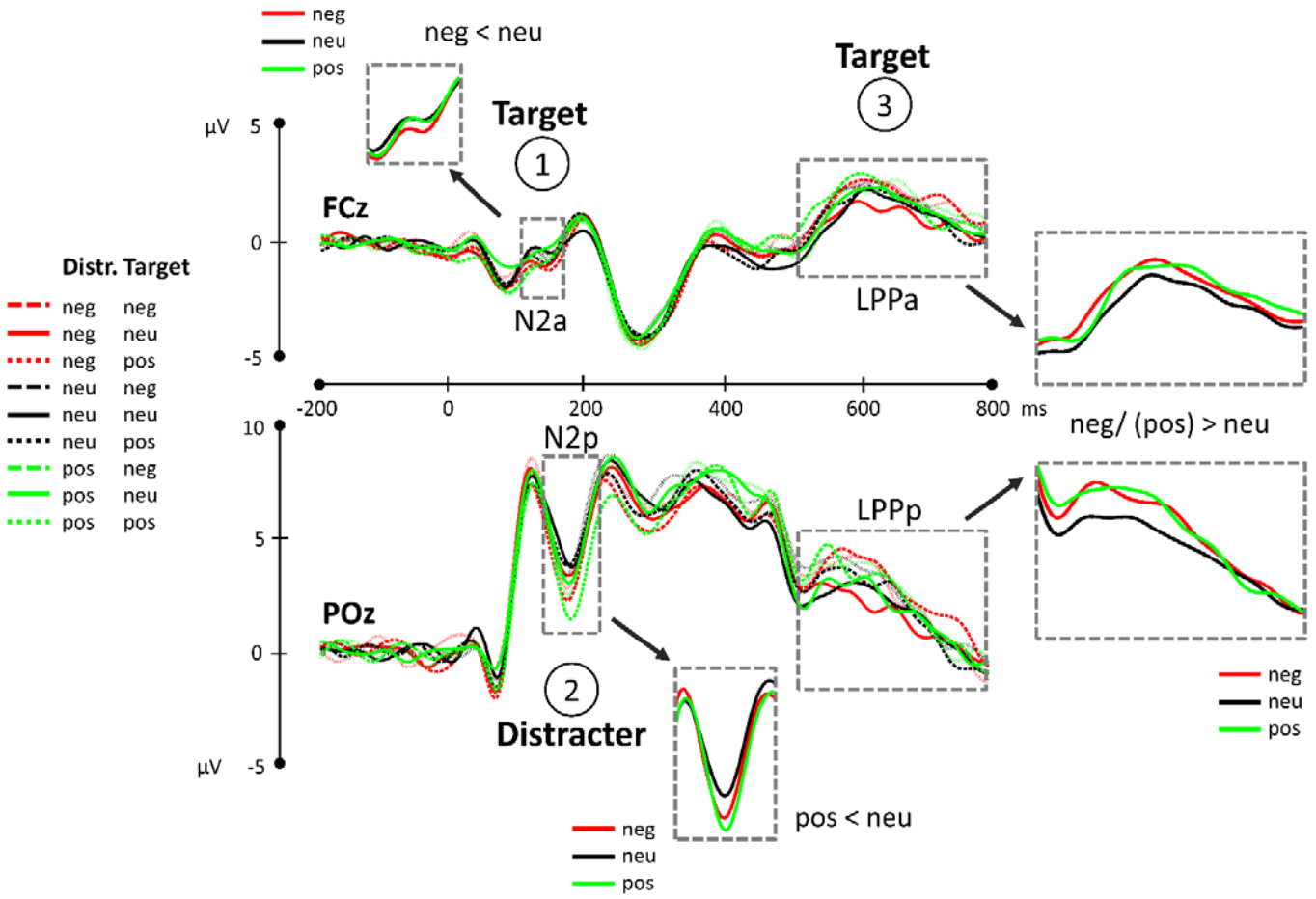


Figure 5. ERP results. Grand averages (depicting all conditions) are shown at FCz and POz, where the experimental effects may be appreciated. Circled digits represent the temporal sequence of these effects. Significant results at each stage are shown as enlarged detail: 1) Negative Targets elicited more pronounced N2a amplitudes than Neutral Targets; 2) Positive Distracters were related to more negative N2p amplitudes than Neutral Distracters; 3) Negative and Positive Targets were associated with greater LPPa and LPPp amplitudes than Neutral Targets.

P2a (182 ms)

At fronto-central scalp regions, where the component shows positive polarity, this result seemed only to become evident when Targets were Neutral, though the effect did not reach significance [$F(2,60) = 2.1$, $p = 0.088$, $\eta^2_p = 0.065$].

iv. P2p (239 ms)

ANOVAs on this component did not find any significant main or interaction effects.

P3p (346 ms)

There were no significant results for P3p at posterior areas.

v. LPPa (600 ms)

LPPa amplitudes were modulated by the emotional content of Targets. Specifically, amplitudes in response to Negative, and marginally to Positive, Target pictures were larger than to Neutral ones [$F(2,60) = 5.1$, $p = 0.009$, $\eta^2_p = 0.145$], as confirmed by post-hoc tests [$p = 0.003$ and $p = 0.081$, respectively].

LPPp (600 ms)

In addition, Negative and Positive Targets elicited higher amplitudes than Neutral ones in LPPp [$F(2,60) = 7.9$, $p = 0.001$, $\eta^2_p = 0.207$], which was shown by Bonferroni pairwise tests [$p < 0.001$, and $p = 0.027$, respectively]. All LPP results are presented in Figure 5 (3). No more significant main or interaction effects were found.

3.5. Discussion

The purpose of the present experiment was to explore effects of competing endogenous and exogenous attention to emotional pictures through behavioral and ERP indices. As indicated before, behavioral studies addressing this issue are scarce and results are contradictory, and it has not been systematically explored at the neural level. Thus, a randomized CDTD task was implemented using emotional pictures as both targets and distracters. At the behavioral level, and based on

previous literature, it was expected that negative picture content would interfere with behavioral performance, lacking a specific hypothesis about the influence of target or distracter status. At the neural level, it was hypothesized that emotional targets and distracters would prompt an effect on the ERP in different moments. Specifically, the influence of targets (endogenous attention) would be visible in more pronounced amplitudes at early (N1, P2, N2, and/or EPN) and late latencies (LPP), for emotional compared to neutral targets. The modulation due to distracters (exogenous attention) would be evidenced by enhanced amplitudes only of early ERP components (P2 and/or N2), for emotional relative to neutral distracters.

Results showed that behavioral data were sensitive to the emotional content of targets, rather than to the content of distracters, since a significant effect of targets was observed for error rates. Specifically, higher error rates were found for negative compared to neutral and positive targets, which most probably reflects the interfering effect of the negative content of these pictures. This finding is consistent with previous evidence pointing to the existence of a negativity bias at the behavioral level, which leads to an impairment of task performance when the negative content of target stimuli is not task-relevant (De Cesarei & Codispoti, 2006; Hajcak & Nieuwenhuis, 2006a; Lichtenstein-Vidne et al., 2012). The finding that the modulating effect on error rates was observed for targets and not for distracters is a novel outcome and inconsistent with the two studies which have reported that error rates were sensitive to the emotional content of distracters, employing a similar task paradigm (MacNamara & Hajcak, 2009; 2010).This may be due to the different exposure durations employed in both studies: in the present Thesis, stimuli were displayed during a short period of 350 ms, while, in the cited studies, a stimulus duration of 1000 ms was used. Consequently, the brief presentation precluded distracters from being endogenously attended, since endogenous attention was focused on targets at this moment in order to accomplish the task. Contrarily, longer durations facilitated later endogenous attention towards distracters after dealing with the task, so that effects could be more easily manifested in the behavioral outcome.

Moreover, reaction times were also modulated by the emotional content of the task; specifically, an interaction effect between target and distracter content was found, thus, reaction times were faster in response to negative and positive target pictures, compared to neutral ones, only when distracters were negative. This finding mainly fits with previous results reported for reaction times, where the emotional content of both kinds of stimuli has also shown an interaction (Lichtenstein-Vidne et al., 2012; Vromen et al., 2016). As argued by the authors, this may be due to the fact that an effect on reaction times is only likely when targets and distracters share features (i.e., when they are both emotional), so that emotion is relevant during the whole cognitive response elicited by the stimulus. However, the finding is inconsistent with the majority of studies, which report an interference effect when negative distracters are present (Buodo et al., 2010; Carretié et al, 2011; 2012; Keil et al., 2005; MacNamara & Hajcak, 2009; 2010; Schönwald & Müller, 2014; Tiferet-Dweck et al., 2016). Hence, it should be taken with caution and it should be confirmed in future studies.

At the neural level, as expected, a significant modulatory effect of the emotional content of both targets and distracters was observed. Target content was the earliest manifesting an influence on ERP amplitudes; thus, N2a (peaking at 140 ms) amplitudes were greater in response to negative targets than to neutral ones at fronto-central sites. This is in line with previous studies reporting an effect of emotional pictures on a negative waveform around similar latencies (Foti et al., 2009; Franken et al., 2008; Keil et al., 2002; Yuan et al., 2014), though the cited negative component was labeled N1, while the component labeled N2 usually appeared later (Amrhein et al., 2004; Cuthbert et al., 2000; Keil et al., 2001; Palomba et al., 1997). However, a negativity bias —as observed here— has been previously found only when participants were engaged in a stimulus categorization task, similar to the present one (Carretié et al., 2007; Delplanque et al., 2004).

Emotional distracters started to influence the ERP course from 180 ms; specifically, positive distracters elicited significantly greater amplitudes than neutral ones in theN2p component. This result fits with the modulation of N2 by

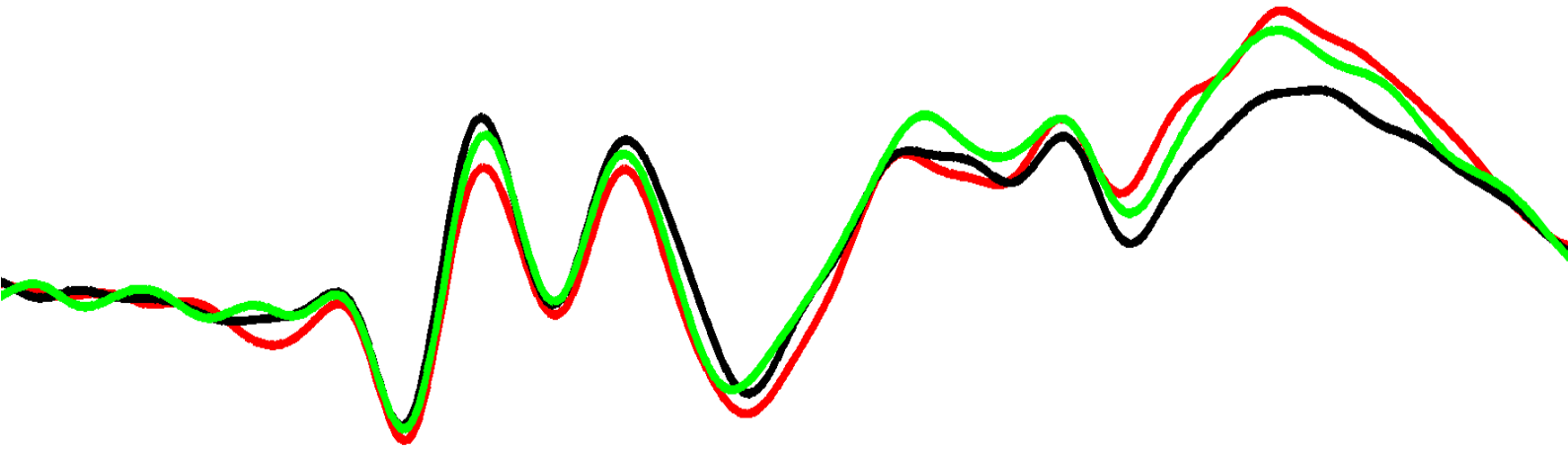
emotional distracters reported by previous studies (Buodo et al, 2012; Carretié et al., 2004; Feng et al., 2012), where a positivity offset was the most frequent result, though at anterior sites. Interestingly, in the P2a component, the present result only tended to become evident when targets were neutral. P2a has been reported as being sensitive to emotional exogenous attention previously (Carretié et al., 2004; 2011; 2012; Feng et al., 2012). This marginally significant interaction in P2a may be due to the competition between emotional targets and distracters at this stage; thus, when emotional targets are present, exogenous attentional processes reflected in P2a may not be triggered to the same extent by emotional distracters.

Finally, attentional resources seemed to be reoriented again to targets, thus, their affective content modulated ERP amplitudes at late latencies, as hypothesized, and as reported by the two previous electrophysiological studies employing a similar task (MacNamara & Hajcak, 2009; 2010). Specifically, emotional target pictures were associated with larger LPP (peaking at 600 ms) amplitudes than neutral ones for both LPPa and LPPp, though positive pictures were only marginally different from neutral ones in LPPa. This result is consistent with a large body of previous evidence showing a modulatory effect of negative (Bradley et al., 2007; Carretié et al., 2006; Delplanque et al., 2005; Foti et al., 2009; Ito et al., 1998; Keil et al., 2002; Wood & Kisley, 2006), or negative and positive pictures on LPP (e.g., Amrhein et al., 2004; Codispoti et al., 2006; 2007; 2009; De Cesarei & Codispoti, 2006; 2011b; Delplanque et al., 2006; Ferrari et al., 2011; 2016; Hajcak et al., 2006a, 2007; Keil et al., 2001; Olofsson & Polich, 2007; Sabatinelli et al., 2007; 2013; Schupp et al., 2003b; 2004a; 2004b;2013). In these studies, LPP was usually maximal at posterior regions (i.e., as current LPPp), though emotional effects have also been observed at anterior sites (i.e., as in current LPPa).

According to the present electrophysiological results, competing endogenous and exogenous attention processes seem to take place serially and independently. The effects mainly present an endogenous–exogenous-endogenous time pattern, beginning at early latencies with a modulation by emotional targets, switching to emotional distracters, and again to emotional targets at late latencies.

However, present data do not provide significant evidence of an interaction of the endogenous and exogenous course when occurring during the same task; thus, the interaction effect observed in behavioral data was mainly inconclusive, and the ERP effect was only marginally significant. In summary, results of the present experiment provide evidence supporting the idea that endogenous and exogenous attention to emotional stimuli, and under current experimental conditions, seem to be functionally segregated processes following mainly a serial pattern, as reflected in the ERPs. However, although random stimulus presentation —as employed here— fits with the most extended praxis in Cognitive and Affective Neuroscience, outside the laboratory, emotional events are often more long-lasting, especially in the case of targets; thus, a quick and random presentation of targets approaches real situations insufficiently. The introduction of voluntarily attended emotional events lasting in time and generating an affective context, which is absent during a brief randomized presentation, would be of high interest. Moreover, emotional contexts have been reported to enhance attention to emotional information, as detailed in Experiment 2, designed to deal with this issue.

4 EXPERIMENT 2



ABSTRACT

A large body of previous studies using targets of changing emotional content (i.e., randomized designs) have shown that both endogenous and exogenous attention preferentially focus on emotional stimuli. Experiment 1 explored the competition of both types of attention in response to emotional targets and distracters using a randomized design. In order to approach real situations, in which endogenous attention is often directed towards long-lasting emotional events, in the present experiment targets were presented in a block design. Importantly, the affective context frequently generated by long-lasting targets has been reported to potentiate attentional effects in previous studies. Hence, participants (N=30) performed a CDTD task presenting negative, neutral, and positive targets in blocks, as well as negative, neutral, and positive distracters in the same fashion as in Experiment 1. Behavioral and electrophysiological indices of both attention modalities were measured. Behavioral data manifested higher error rates in response to negative targets, compared to neutral and positive ones. Neural measures revealed a modulating effect of the emotional content of distracters on N2a and N2p at 268 ms, and of emotional targets on LPPp, peaking at 581 ms. Specifically, N2a amplitudes were more pronounced for positive than for neutral distracter pictures, whereas N2p was enhanced in response to both negative and positive distracters, compared to neutral ones. LPPp amplitudes were higher for negative targets relative to neutral targets. Moreover, compared to Experiment 1, both the N2 and the LPP effects were enhanced, and the influence of arousal at early latencies (N2) was potentiated. There was no evidence of an interaction effect between the emotional content of targets and distracters, either at the behavioral or at the neural level. Thus, in line with Experiment 1, results of the present study evidence that competing endogenous and exogenous attention seem to function in a serial and segregated manner.

ATTENTION TO CONCURRENT EMOTIONAL TARGETS AND DISTRACTERS PRESENTED IN A BLOCK DESIGN

4.1. Introduction

In evolutionary terms, life threatening and sustaining events are preferentially processed, in order to ensure survival. It has been repeatedly confirmed that endogenous and exogenous attention are mainly directed towards these stimuli which are key for survival and, by definition, emotional. Further, in this context, an efficient coordination of the endogenous and exogenous attentional mechanisms, when both are presented with emotional stimuli, is highly important from an adaptive point of view. However, in relation to emotion, the two systems have been explored mainly separately up to now, since only emotional targets (without emotional distracters) or only emotional distracters (with neutral targets) have been presented.

The previous experiment of this Thesis analyzed this issue through behavioral and electrophysiological indices employing a randomized CDTD task, in which both targets and distracters were emotional pictures. Behavioral data reflected an attentional bias towards emotional target content. Neural data showed that endogenous and exogenous attention to emotional stimuli modulated ERPs in a serial and apparently independent way. Specifically, an emotional influence of targets was found at the beginning of the neural response (N2a, peaking at 140

ms), and again at late latencies (LPPa and LPPp, peaking at 600 ms), both phases being associated with endogenous attention, whereas emotion of distracters prompted larger amplitudes in between (N2p, peaking at 182 ms), associated with exogenous attention. While the LPP effect is consistent with previous results obtained in studies also exploring endogenous-exogenous attention competition (MacNamara & Hajcak, 2009; 2010), the early effects were a novel finding. Importantly, no significant interaction between the emotional content of targets and distracters was observed at the neural level, though P2a data showed a tendency. In sum, it was concluded that both endogenous and exogenous attention to emotional targets and distracters, respectively, dominated at different moments and in a serial manner (target – distracter – target). But there was no evidence in favor of an interaction between both attentional systems when dealing with emotion, leaving this question open.

The random presentation of emotional targets is common in previous studies in this field of research. Though this strategy is a recommended choice in order to control for confounding variables, it may not reliably resemble real situations, in which endogenous attention is often directed towards long-lasting events. In attentional tasks, this is especially true in the case of target stimuli. Thus, while natural distracters may often appear abruptly and briefly (e.g., a spider showing up from underneath the cabinet and vanish again immediately afterwards, or a car honking), endogenous attention frequently focuses on long-lasting targets (e.g., being engaged in a book or a conversation). In order to approach real situations, this kind of target presentation should also be taken into account in laboratory studies.

Endogenously attended lasting emotional events would most typically generate an emotional context and, in many cases, an affective state related to this context, which both have been reported to influence attention. With respect to the impact of *context*, studies exploring this issue have generally employed facial expressions or a combination of faces and scenes as emotional stimuli. At the endogenous level, a behavioral study, in which contexts were generated by emotionally charged sounds (e.g., laughter), reported that attention was

preferentially deployed to facial expressions that were congruent with the affective context, as evidenced by faster reaction times (Van Dessel & Vogt, 2012). However, in a study that used short sentences describing emotion-inducing situations, both negative and positive faces were preferentially processed during positive contexts (Diéguez-Risco et al., 2013). Further, employing emotional scenes as context-eliciting elements combined with faces, behavioral evidence is in favor of facilitated processing of affectively congruent facial expressions (Hietanen & Astikainen, 2013; Righart & de Gelder, 2008a; 2008b). ERP results obtained in two recent studies presenting faces within emotional contexts generated by short sentences revealed larger N170 (Diéguez-Risco et al., 2015) and LPP (Diéguez-Risco et al., 2013; 2015) amplitudes for emotionally incongruent trials. In several other studies, the amplitude of N170 in response to emotional facial expressions was also modulated by the emotional context caused by preceding pictures or background pictures. Specifically, N170 amplitudes were significantly increased for any face (emotional and non-emotional) embedded in a negative scene (Righart & de Gelder, 2006; 2008a) or for faces which were emotionally congruent to the context (Hietanen & Astikainen, 2013); however, P1 and EPN showed incongruence effects (Hietanen & Astikainen, 2013). Studies employing only scenes —not combining them with facial expressions— are scarce. In one of them, startle probes following emotional pictures generated larger N1 amplitudes when the context was of negative valence. In contrast, P3 magnitude for both startling and neutral tones was reduced during emotional contexts (Cuthbert et al., 1998). Further, the LPP has been shown to be sensitive not only to the affective content of the target but also to the emotional category of the series in which the target was embedded, where an affective incongruence between the target and the context resulted in an enhancement of the effects observed in this component (Ito et al., 1998; Schupp et al., 2000; Smith et al., 2006). In one ERP study, P1 results also suggested this incongruence effect (Smith et al., 2006). At the exogenous level, evidence in favor of the influence of emotional contexts on attentional capture is even more reduced. In a behavioral study, in which context was created by the description of a negative or positive situation and distracters were letters associated with danger or chance, interference with performance was stronger

when context and distracter type were of opposite valence (Rothermund et al., 2001). Further, an ERP study revealed that negative contexts generated by the presentation of pictures potentiated early attention to red color, as indicated by enhanced P1 amplitudes (Kuniecki et al., 2015). Moreover, hemodynamic results evidenced that a negative context elicited by faces may facilitate attentional capture towards neutral auditory distracters (Domínguez-Borràs et al., 2009).

Moreover, with respect to the impact of *affective states*, negative and positive mood states —which may ultimately be associated with the emotional context (but also with affective dynamics generated internally)— have been found as well to modulate perception and attention. When attending to emotional stimuli, state-congruent biases have been described. At the endogenous level, behavioral data reveal that a negative state may intensify the vigilance to negative stimuli (Chen, Yuan, Huang, Chen, & Li, 2008; Rokke & Lystad, 2015; Yuan et al., 2014), while a positive state may lead to preferentially attend to positive targets (Rokke & Lystad, 2015; Wadlinger & Isaacowitz, 2006). However, there are other data evidencing that emotional states may elicit attention allocation to stimuli of opposite valence (Schwager & Rothermund, 2013). Concerning ERP data, enhancing effects by negative and positive mood on endogenous attention have been described at both early and late processing stages (e.g., P1: Moriya & Nittono, 2011; LPP: Yuan et al., 2014). At the exogenous level, behavioral data suggest that the emotional content of distracters may interact with the mood state (Wentura, Voss, & Rothermund, 2009) and with the anxiety level of participants (MacNamara & Hajcak, 2010), eliciting both congruent and incongruent effects. Employing ERPs, the influence of the affective state on exogenous attention during CDTD tasks has been generally explored for neutral distracters (Rossi & Pourtois, 2012, in press; Vanlessen, Rossi, De Raedt, & Pourtois, 2013; 2014), revealing that mood may amplify distracter processing at earliest stages (C1). However, recent data also confirm an interaction effect of the participants' affective state with exogenous attention to emotional distracters in LPP (Carboni, Kessel, Capilla, & Carretié, under review). Additionally, fMRI data also demonstrate that the affective state may influence neural control processes underlying the resolution of cognitive

interference (Melcher, Born & Gruber, 2011); specifically, it has been observed that negative mood may alter the selection of task-relevant information when presented with task-irrelevant emotional distraction.

In conclusion, according to the evidence reviewed above, it may clearly be assumed that emotional contexts and affective states show an impact on attention, and specifically, on attention to emotional information. Nevertheless, due to the variety of task designs and stimulus types, the kind of influence remains inconclusive; thus, it is unclear whether context-stimulus congruence or incongruence causes the attentional effects. Hence, in the present Thesis, it may be expected that presenting emotional targets following a block design (i.e., targets within each emotional category —negative, neutral, and positive— are presented consecutively) will potentially reinforce the affective modulation of endogenous and exogenous attention, though it is uncertain whether the attentional potentiation will be associated with the emotional congruence or incongruence between target and distracter contents. Accordingly, the present study explored competing endogenous and exogenous attention to emotional stimuli through behavioral and neural indices, employing an affective CDTD task, in which emotional categories of targets were blocked, generating an affective context, while distracters were presented in random order. At the behavioral level, it was hypothesized that the emotional content of target pictures would interfere with task performance (identical to Experiment 1) by increasing reaction times and/or error rates in the experimental task. As in Experiment 1, a negativity bias was expected. Moreover, an additional effect of emotional distracters on behavioral indices might appear, if attention to distracters is indeed broadened by the emotional context created by target pictures. At the neural level, it was hypothesized that both emotional targets and distracters would modulate ERP amplitudes (as observed in Experiment 1); thus, an influence of emotional targets arranged in affective contexts would be reflected in more pronounced amplitudes (with respect to neutral ones) of early components (N1, P2, N2, and/or EPN), and of the late LPP. Based on previous studies and Experiment 1, at early stages, target valence will probably elicit the attention effects, whereas, at late stages, it will be

target arousal. It was also expected that emotional distracters would capture attention, and that this would cause enhanced amplitudes of early ERP components (P2 and/or N2). Consistent with Experiment 1, it was hypothesized that this effect would be in favor of negative or positive distracters, compared to neutral ones. Importantly, an influence of the emotional context is expected at both the behavioral and the neural level; thus, experimental effects will be potentiated by the context, and this will be reflected both quantitatively (increase of experimental effect sizes) and qualitatively (the influence of target valence and arousal might vary with respect to Experiment 1). At this respect, the interaction between emotional targets and distracters was also expected to reach significance.

4.2. Objectives and hypotheses

Accordingly, Experiment 2 addressed the objectives 1-4 of the Thesis (see Section 2):

1. To explore how the competition between endogenous and exogenous attention is reflected at the behavioral level, and whether there is any advantage of one modality over the other and/or any interaction effect.
2. To disentangle the neural time course of the competing attention effects, and to determine whether both responses are reflected in the ERP in a parallel manner or in a serial order.
3. To analyze how valence and arousal of stimuli modulate the exogenous-endogenous competition.
4. To compare the influence of a random versus a block (contextual) design on competing endogenous and exogenous attention.

These objectives were associated with the hypotheses 1-4 (see Section 2):

1. Increased reaction times and/or error rates will be observed in response to negative targets and to negative distracters, compared to neutral ones.

2. Emotional targets will yield higher amplitudes than neutral ones at both early (N1, P2, N2, and/or EPN) and late latencies (LPP); emotional distracters, in comparison with neutral ones, will produce enhanced amplitudes only in early components (P2 and/or N2).
3. Valence will modulate ERPs at early latencies (N1, P2, N2, and/or EPN), whereas arousal effects will appear at late latencies (LPP).
4. Experimental effects revealed by the random task design (Experiment 1) will be amplified when using the contextual design (Experiment 2).

4.3. Methods

4.3.1. Participants

Thirty-two students from the Universidad Autónoma de Madrid (different from those participating in Experiment 1), took part in Experiment 2, although only data from 30 could be analyzed. Ages of these 30 participants (25 women) ranged from 18 to 27 (mean = 20.8, standard deviation = 2.3), and did not differ from ages of the participants of Experiment 1 [$t(59) = -1.9$; corrected $p > 0.05$]. All of them participated voluntarily after providing informed consent according to the Declaration of Helsinki, and received €10 for their participation. They reported normal or corrected to normal visual acuity. The study had been previously approved by the Research Ethics Committee of the Universidad Autónoma de Madrid.

4.3.2. Stimuli and Procedure

Participants were placed in an electrically shielded, sound-attenuated and video-monitored room, at a distance of 70 cm from the screen. Pictures were presented on a ViewPixx screen using Psychtoolbox 3 task programming extensions for Matlab (Brainard, 1997; Kleiner et al., 2007). Stimuli were the same as those employed in Experiment 1, thus, they were composed of two identical target pictures in the center of the screen superposed on a distracter picture filling the background (Figure 1). Thus, there were 40 trials of each combination of Target

(Negative, Neutral, Positive) × Distracter (Negative, Neutral, Positive), half of them showing targets in mirror orientation. These stimuli were obtained by combining 20 different negative, neutral and positive target and distracter pictures, each of them presented two times. Consequently, there were 120 trials of each emotional target (120 negative, 120 neutral, and 120 positive), from which 40 were combined with negative, 40 with neutral and 40 with positive distracters. Unlike Experiment 1, these 120 pictures of the same emotional target were displayed together in the same block. Thus, there were three blocks of targets: one in which all targets were negative, one neutral, and one positive. These three blocks were arranged in six semi-random orders balanced across participants, and were presented separated by a short rest period. Within each block, emotional distracters were displayed randomly. As in Experiment 1, visual angle of the whole stimulus was 41.1° (width) × 23.8° (height), and size of the two target images together was 11.4° (width) × 4.7° (height). All stimuli were displayed on the screen for 350 ms, followed by a white fixation cross on a black screen of 2650 ms. Participants were instructed to look continuously at the center of the screen, to press —as accurately and rapidly as possible— one key if the target pictures were shown in mirror orientation, and a different key if they were not, and to refrain from blinking during stimulus presentation. Before starting the experiment, they completed a practice block of ten trials.

As mentioned above, the pictures were the same as in Experiment 1, taken from the EmoMadrid database according to valence and arousal average normative ratings. As previously demonstrated, pictures were selected so that valence equally differed from negative to neutral and from neutral to positive, while arousal was similar for negative and positive stimuli, but higher than for neutral stimuli. Additionally, all valence and arousal scores were balanced between targets and distracters. The whole sample of pictures was equivalent in luminosity and spectral density in eight frequency bands (768-384, 384-192, 192-96, 96-48, 48-24, 24-12, 12-6, 6-3 cycles/image, and residual). Results of ANOVAs confirming these properties may be found in Table 1b, and a further description is included in the Methods section of Experiment 1. Moreover, participants' own assessments of

valence and arousal were also measured at the end of the recording session (Table 4a).

4.3.3. Recording and pre-processing

EEG was recorded using an electrode cap (ElectroCap International) with 59 tin electrodes placed at the scalp following the distribution of the International 10-20 System and referenced to the nose tip. EOG data were recorded supra- and infraorbitally as well as from the left versus right orbital rim. An online analog bandpass filter of 0.3 Hz to 10 kHz was applied, and recordings were digitized at a sampling rate of 420 Hz. The continuous recording was divided into 1000 ms epochs for each trial, beginning 200 ms before stimulus onset. Behavioral activity was measured through a numeric keypad. Outlier trials (with responses before 200 ms or after 2000 ms), incorrect trials, and trials with no response were eliminated. An offline digital bandpass filter of 0.3 to 20 Hz was applied using Fieldtrip software (Oostenveld et al., 2011). Ocular artifact removal was carried out through an Independent Component Analysis based strategy (Jung et al., 2000) —as implemented in this software—, and through subsequent visual inspection. The average number of trials accepted within each stimulus category after this rejection of artifacts and incorrect responses is included in Table 6a. A minimum criterion of 20 correct and artifact-free trials per condition and participant was set to ensure a reasonable signal-to-noise ratio of the ERP averages. Data from two participants could not be analyzed because of non-solvable anomalies in the recordings of several EEG leads (N=1), or a very high number of erroneous behavioral responses (N=1).

4.3.4. Data analysis

In all ANOVAs described below, post-hoc comparisons were performed to determine the significance of pairwise contrasts using the Bonferroni correction procedure. Effect sizes were computed using the partial eta-square (η^2_p) method. The analyses were carried out using SPSS 19.0 software package (IBM SPSS, 2010).

4.3.4.1. Assessment of pictures

Two-way repeated-measures 2×3 ANOVAs were applied for both the dimension of Valence and of Arousal, with Stimulus (Target, Distracter) × Emotion (Negative, Neutral, Positive) as factors.

Table 4. (a) Means and standard deviations (in parenthesis) of participants' assessment of pictures. (b) ANOVA results of picture assessment.

(a)	Target			Distracter		
	Negative	**Neutral**	**Positive**	**Negative**	**Neutral**	**Positive**
Subjective ratings of pictures						
Valence (1=negative to 5=positive)	2.06	3.09	4.25	1.96	3.08	4.26
	(0.35)	(0.15)	(0.32)	(0.36)	(0.22)	(0.36)
Arousal (1=negative to 5=positive)	3.84	2.96	3.88	3.98	2.87	3.94
	(0.39)	(0.28)	(0.52)	(0.40)	(0.26)	(0.52)

(b)	*F*	*df*	*p*	ηp^2
Valence				
Target-Distracter	0.4	1,29	0.556	0.012
Emotion	554.4	2,58	< 0.001***	0.950
neg - neu			< 0.001***	
neg - pos			< 0.001***	
neu - pos			< 0.001***	
Emotion × Target-Distracter	2.2	2,58	0.119	0.071
Arousal				
Target-Distracter	0.3	1,29	0.582	0.011
Emotion	133.3	2,58	< 0.001***	0.821
neg - neu			< 0.001***	
neg - pos			1.000	
neu - pos			< 0.001***	
Emotion × Target-Distracter	6.7	2,58	0.002**	0.188
neg			0.100	
neu			0.250	
pos			0.376	

4.3.4.2. Behavioral data

Reaction times (in milliseconds) and error rates (ranging from 0 to 1) were submitted to two-way repeated 3×3 ANOVAs introducing Target (Negative, Neutral, Positive) and Distracter (Negative, Neutral, Positive) as factors; outliers

were omitted. Means and standard deviations of behavioral data are presented in Table 5a.

4.3.4.3. ERP data

a) Detection, spatio-temporal characterization, and quantification of relevant ERP components

As in Experiment 1, a two-step PCA was employed to detect and quantify relevant ERP components. As explained earlier in Experiment 1, PCA has repeatedly been recommended for these purposes (e.g., Chapman & McCrary, 1995; Chapman et al., 2004; Dien, 2010; 2012; Dien et al., 2005; 2007). This technique, –compared to traditional, visual inspection-based methods–, employs mathematical, more objective criterions when defining temporal windows and spatial regions, avoiding subjectivity or inter-judge discrepancies and offering more reliable results. In brief, in a first step, it computes the covariance between time points to obtain ERP components (tPCA), and, in a second step, the covariance between electrodes in order to determine scalp regions (sPCA). For a detailed description on PCA please see the Methods section of Experiment 1.

The PCA was carried out on the covariance matrix (Dien et al., 2005); the decision on the number of factors to select was based on the scree test (Cliff, 1987); and extracted factors were submitted to promax rotation (Dien, 2010; 2012; Dien et al., 2005; 2007). Statistical analyses for each ERP component were then computed on spatial factor scores which are linearly related to amplitudes.

b) Scalp ERP analysis

Two-way repeated-measures 3×3 ANOVAs on spatial factor scores were carried out for relevant temporal factors, with respect to Target (Negative, Neutral, Positive) and Distracter (Negative, Neutral, Positive).

4.4. Results

4.4.1. Assessment of pictures

ANOVAs on participants' ratings on Valence and Arousal showed, first, that stimulus Valence was as assumed a priori, second, that Negative and Positive pictures were balanced with respect to their Arousal levels, and third, that there were no differences between Targets and Distracters. Specifically, significant differences between emotional categories were obtained in both dimensions [Valence: $F(2,58) = 554.4$, GG corrected $p < 0.001$, $\eta^2_p = 0.950$; Arousal: $F(2,58) = 133.3$, $p < 0.001$, $\eta^2_p = 0.821$]. Additionally, Bonferroni corrected post-hoc contrasts indicated that Negative and Positive pictures showed different Valence [$p < 0.001$] but not different Arousal levels ($p > 0.05$), and that they differed from Neutral pictures in both dimensions [all $p < 0.001$]. There were no differences between Target and Distracter pictures [Valence: $F(1,29) = 0.4$, $p > 0.05$; Arousal: $F(1,29) = 0.3$, $p > 0.05$]. Results are summarized in Table 4b.

Table 5. (a) Means and standard deviations (in parenthesis) of behavioral data. (b) ANOVA results of behavioral data.

(a)	Neg distracter			Neu distracter			Pos distracter		
	Neg target	Neu target	Pos target	Neg target	Neu target	Pos target	Neg target	Neu target	Pos target
Behavior									
Reaction times (ms)	869	902	905	868	902	896	869	890	892
	(151)	(164)	(181)	(141)	(180)	(176)	(151)	(163)	(164)
Error rates (%)	16.7	12.5	9.4	14.5	11.5	9.1	17.4	10.3	9.9
	(7.6)	(9.6)	(8.1)	(6.2)	(9.6)	(7.5)	(6.9)	(8.4)	(8.7)

(b)	*F*	*df*	*p*	ηp^2
Reaction times				
Target	1.9	2,58	0.165	0.060
Distracter	0.4	2,59	0.655	0.014
Target × Distracter	0.3	4,116	0.849	0.012
Error rates				
Target	26.6	2,58	< 0.001***	0.478
neg - neu			< 0.001***	
neg - pos			< 0.001***	
neu - pos			0.082	
Distracter	0.8	2,58	0.436	0.028
Target × Distracter	1.7	4,116	0.150	0.056

4.4.2. Behavioral data

Given that behavioral indices lacked normal distribution, data transformations were applied to the original data in order to achieve normality. Reaction times were transformed computing the inverse value (1/[reaction times]), as recommended for this kind of distribution (Tabachnick & Fidell, 2001), and error rates were arcsin-root transformed (arcsin[√error rates]), as appropriate for data which lie between an upper and lower bound (Zar, 1996). ANOVAs introducing Target (Negative, Neutral, Positive) and Distracter (Negative, Neutral, Positive) as factors were then performed on these normally transformed data, though Table 5a includes the original ones for facilitating interpretation.

ANOVAs on error rates yielded a significant main effect of Target [$F(2,58) = 26.6$, $p < 0.001$, $\eta^2_p = 0.478$]. Bonferroni corrected post-hoc tests indicated that significantly higher error rates were associated with Negative Targets, compared to Neutral and Positive ones (both $p < 0.001$). ANOVA results are shown in Table 5b. In the case of reaction times, there were no significant main or interaction effects.

4.4.3. ERP data

a) Detection, spatio-temporal characterization, and quantification of relevant ERP components

Figure 7a and Figure 8 show grand averages after subtracting the baseline activity (200 ms of prestimulus recording) from each ERP. Nine temporal factors were extracted through tPCA, as shown in Figure 7b. sPCAs subsequently applied to these temporal factor scores extracted two spatial factors for each temporal factor, one anterior or fronto-central (which will be named with the letter “a”), and one posterior or parieto-occipital (which will be denominated “p”).

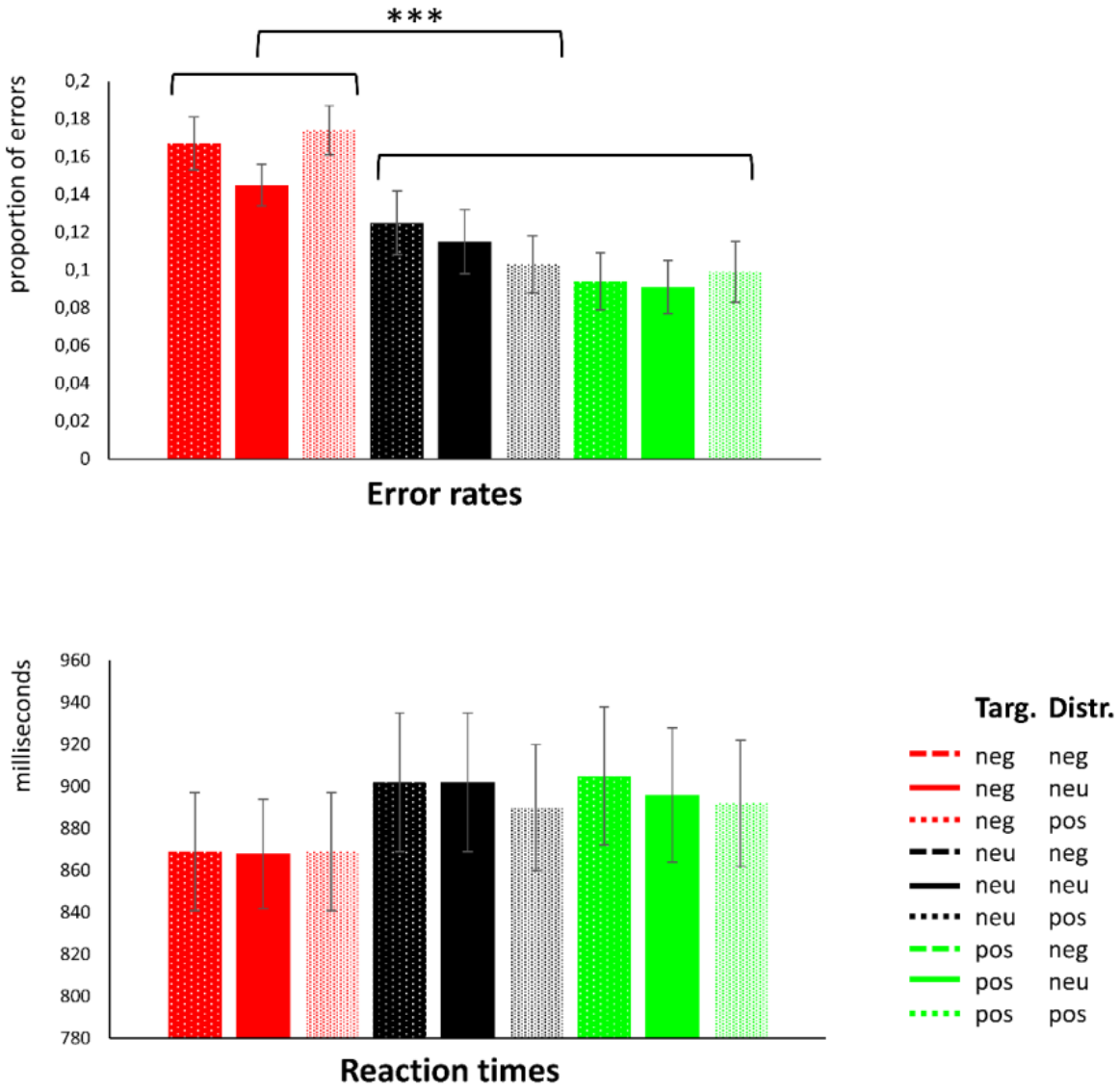


Figure 6. Behavioral results.

From the nine temporal factors, five were relevant to the hypotheses of this study. Table 6a includes mean factor scores and standard deviations of the five components at all its scalp regions. As shown in Figure 7, in chronological order, the first temporal factor was TF 7 (peaking at 125 ms), a positive waveform at posterior sites corresponding to P1p; at frontal areas, the corresponding component was a P1a-like positive peak, but it was not clearly distinguishable. The second relevant factor was TF 6, a negative component at both fronto-central and

parieto-occipital sites, peaking at 173 ms, and therefore associated with N1a and N1p. The third one was TF 2, a negative component peaking at 268 ms, which best matches with the N2a wave at anterior scalp regions, and with N2p at posterior ones. The fourth relevant factor was TF 3, with its peak at 418 ms, a positivity associated with P3, both at fronto-central (P3a) and at parieto-occipital areas (P3p). Finally, the last one was TF 1, a late positivity peaking at 581 ms, and therefore denominated LPPa at anterior electrodes and LPPp at posterior electrodes. The P2 component was not detected by the tPCA. These labels will be employed hereafter in order to make results easier to understand. Please see Figure 8 for the correspondence of labels and ERP components, and Table 6b for further information on spatial regions.

b) Experimental effects on scalp ERP components

Following the PCA, the spatial factor scores of each of the five temporal factors were submitted to ANOVAs on Target (Negative, Neutral, Positive) × Distracter (Negative, Neutral, Positive). As previously indicated, factor scores are directly related to amplitudes. Results are summarized in Figure 9, and in Table 6b, where *F*-ratios and the corresponding *p* values of all contrasts can be found.

i. P1a (125 ms)

ANOVAs on P1a did not manifest any significant main or interaction effects.

P1p (125 ms)

In case of P1p, there were no significant results.

ii. N1a (173 ms)

There were no significant main or interaction effects, though the main effect of Targets was close to significance [$F(2,58) = 2.9$, $p = 0.061$, $\eta^2_p = 0.092$], Positive Targets eliciting more negative N1a amplitudes than Neutral ones [$p = 0.062$].

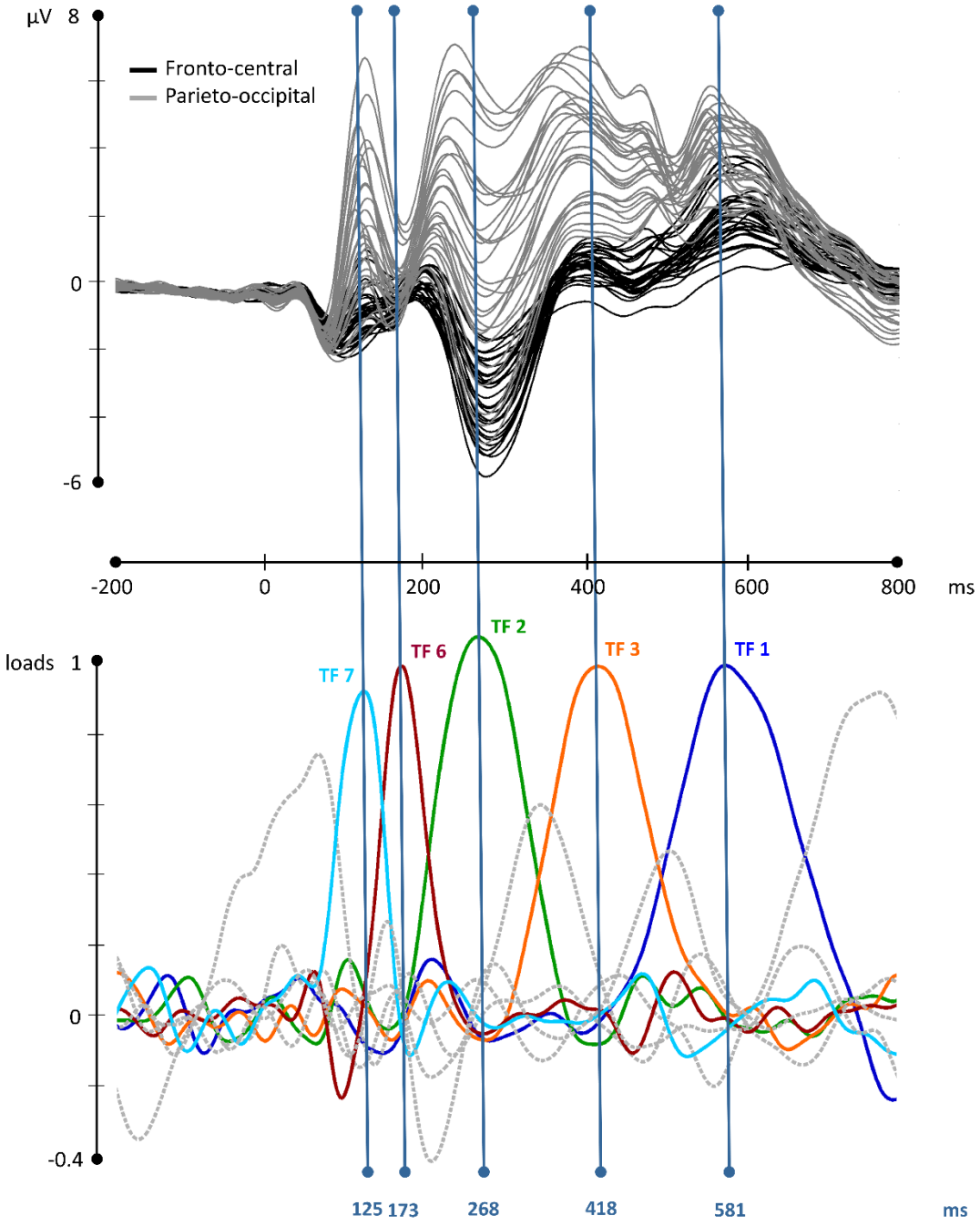


Figure 7. (a) Grand averages across all conditions at 59 sites. Fronto-central electrodes are drawn in black, and parieto-occipital electrodes in gray. (b) tPCA factor loadings after promax rotation. Relevant temporal factors are highlighted in color. Blue vertical lines indicate the correspondence of temporal factors and ERP components at anterior and posterior scalp regions.

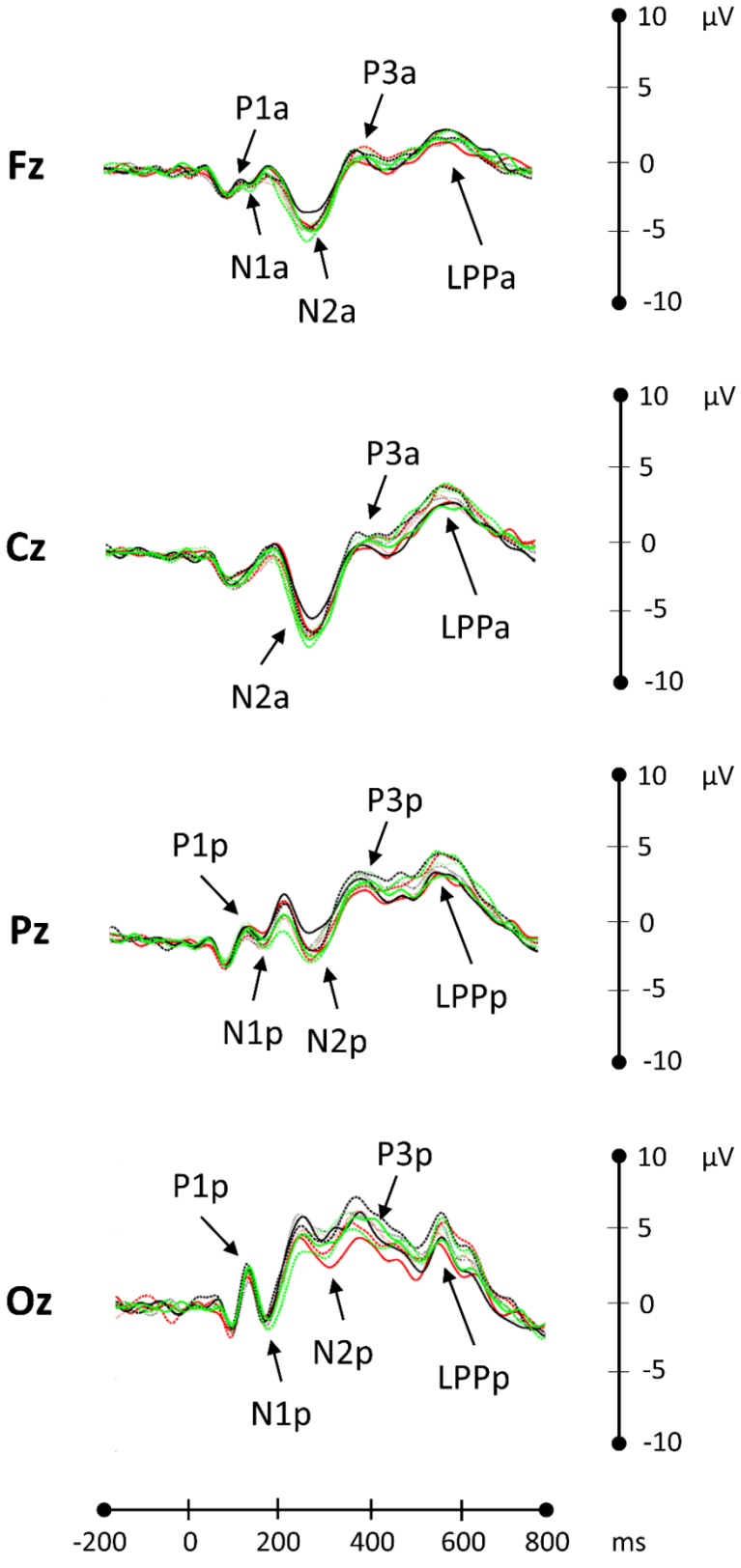
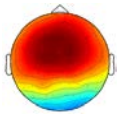
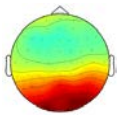
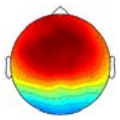
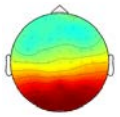
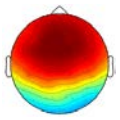
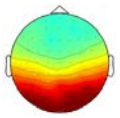
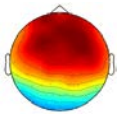
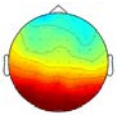
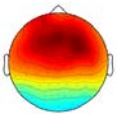
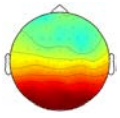


Figure 8. Grand averages at selected midline electrodes. All relevant components extracted through PCA are designated by its label.

Table 6. (a) Neural data. i) Average number of valid trials. ii) Means and standard deviations (in parenthesis) of neural data. (b) ANOVA results of neural data. Topographical plots represent sPCA factor loadings after promax rotation; please note that, even if the component appears as a negative peak in the grand average, loadings are always positive.

(a)	Neg distracter			Neu distracter			Pos distracter		
	Neg target	**Neu target**	**Pos target**	**Neg target**	**Neu target**	**Pos target**	**Neg target**	**Neu target**	**Pos target**
Trials									
Average nº of trials	33.3	35.0	36.2	34.2	35.4	36.4	33.0	35.9	36.0
	(3.0)	(3.9)	(3.2)	(2.5)	(3.8)	(3.0)	(2.8)	(3.4)	(3.5)
Scalp level ERPs									
P1a (factor scores)	-0.069	0.049	-0.094	0.093	0.082	-0.199	-0.016	-0.049	0.203
	(0.963)	(0.962)	(1.138)	(1.041)	(1.152)	(0.977)	(1.021)	(0.955)	(0.826)
P1p (factor scores)	-0.088	0.002	-0.017	0.005	-0.042	-0.204	0.070	0.044	0.230
	(0.983)	(0.939)	(1.021)	(1.072)	(1.144)	(0.904)	(1.093)	(1.084)	(0.786)
N1a (factor scores)	-0.084	0.145	-0.203	0.130	0.135	-0.045	-0.083	0.123	-0.117
	(0.965)	(1.004)	(1.124)	(1.000)	(0.977)	(0.892)	(1.056)	(1.165)	(0.832)
N1p (factor scores)	-0.082	0.109	-0.058	0.129	0.106	0.050	-0.172	0.025	-0.107
	(0.842)	(0.820)	(1.087)	(1.166)	(0.846)	(0.977)	(0.960)	(1.213)	(1.088)
N2a (factor scores)	-0.001	0.097	-0.100	0.048	0.306	0.026	-0.263	-0.027	-0.087
	(0.997)	(1.067)	(0.912)	(1.028)	(0.989)	(0.867)	(1.076)	(1.079)	(0.999)
N2p (factor scores)	-0.122	-0.072	0.000	0.035	0.220	0.150	-0.227	-0.077	0.093
	(1.017)	(0.820)	(0.994)	(1.057)	(0.929)	(0.952)	(1.050)	(1.115)	(1.085)
P3a (factor scores)	0.095	-0.133	-0.129	0.151	-0.115	0.051	0.002	0.002	0.077
	(1.015)	(0.892)	(1.163)	(1.038)	(0.846)	(1.046)	(1.026)	(0.867)	(1.143)
P3p (factor scores)	-0.126	-0.234	0.000	0.199	-0.050	0.159	-0.083	0.007	0.128
	(1.020)	(0.771)	(1.099)	(1.047)	(0.930)	(1.008)	(0.984)	(1.022)	(1.128)
LPPa (factor scores)	0.118	-0.136	-0.156	0.123	-0.091	0.037	0.128	-0.109	0.086
	(0.954)	(1.048)	(1.182)	(1.011)	(0.873)	(0.959)	(1.028)	(0.892)	(1.087)
LPPp (factor scores)	0.177	-0.313	-0.100	0.293	-0.205	0.052	0.252	-0.258	0.101
	(0.776)	(1.014)	(1.210)	(0.982)	(0.916)	(0.852)	(1.012)	(0.958)	(1.130)

(b)	*TF*	*SF*		*F*	*df*	*p*	ηp^2
			**P1a**				
			Target	0.1	2,58	0.888	0.004
			Distracter	0.2	2,58	0.814	0.007
	7		Target × Distracter	1.4	4,116	0.241	0.046
			**P1p**				
			Target	0.0	2,58	0.996	0.000
			Distracter	2.0	2,58	0.150	0.063
			Target × Distracter	1.2	4,116	0.316	0.040
			**N1a**				
			Target	2.9	2,58	0.061	0.092
			neg - neu			0.569	
			neg - pos			0.909	
			neu - pos			0.062	
			Distracter	0.6	2,58	0.566	0.019
	6		Target × Distracter	0.3	4,116	0.892	0.010
			**N1p**				
			Target	1.6	2,58	0.211	0.052
			Distracter	3.0	2,58	0.060	0.093
			neg - neu			0.521	
			neg - pos			0.862	
			neu - pos			0.087	
			Target × Distracter	0.6	4,116	0.692	0.019
			**N2a**				
			Target	2.9	2,58	0.063	0.091
			neg - neu			0.055	
			neg - pos			1.000	
			neu - pos			0.220	
	2		Distracter	6.1	2,58	0.004**	0.175
			neg - neu			0.310	
			neg - pos			0.238	
			neu - pos			0.004**	
			Target × Distracter	1.2	4,116	0.296	0.041
			**N2p**				
			Target	2.8	2,58	0.071	0.087
			neg - neu			0.345	
			neg - pos			0.063	
			neu - pos			1.000	
	2		Distracter	7.4	2,58	0.001**	0.203
			neg - neu			0.008**	
			neg - pos			1.000	
			neu - pos			0.005**	
			Target × Distracter	1.6	4,116	0.192	0.051
			**P3a**				
			Target	1.0	2,58	0.360	0.035
			Distracter	0.6	2,58	0.538	0.021
			Target × Distracter	0.8	4,116	0.512	0.028
			**P3p**				
	3		Target	2.3	2,58	0.109	0.074
			Distracter	3.1	2,58	0.050	0.098
			neg - neu			0.087	
			neg - pos			0.422	
			neu - pos			0.887	
			Target × Distracter	1.3	4,116	0.285	0.042
			**LPPa**				
			Target	2.1	2,58	0.130	0.068
			Distracter	0.9	2,58	0.404	0.031
			Target × Distracter	0.4	4,116	0.777	0.015
			**LPPp**				
	1		Target	9.8	2,58	< 0.001***	0.253
			neg - neu			< 0.001***	
			neg - pos			0.125	
			neu - pos			0.127	
			Distracter	1.5	2,58	0.236	0.049
			Target × Distracter	0.1	4,116	0.968	0.005

N1p (173 ms)

Likewise, no significant results were found for N1p, though the main effect of Distracters was also marginally significant [$F(2,58) = 3.0$, $p = 0.060$, $\eta^2_p = 0.093$], thus, Positive Distracters would prompt more pronounced N1p amplitudes than Neutral Distracters [$p = 0.087$].

iii. N2a (268 ms)

For N2a (measured at fronto-central electrodes), a significant main effect was evident for Distracters [$F(2,58) = 6.1$, $p = 0.004$, $\eta^2_p = 0.175$]. Specifically, Bonferroni pairwise tests indicated that amplitudes associated with Positive Distracters were more negative than those of Neutral Distracters [$p = 0.004$], as presented in Figure 9 (1). Moreover, results manifested a marginally significant modulation of Target [$F(2,58) = 2.9$, $p = 0.063$, $\eta^2_p = 0.091$], where Negative Targets would elicit smaller amplitudes relative to Neutral ones [$p = 0.055$]. There was no significant interaction effect.

N2p (268 ms)

ANOVAs on this parieto-occipital component also yielded a significant main effect of Distracters [$F(2,58) = 7.4$, $p = 0.001$, $\eta^2_p = 0.203$]. Post-hoc tests showed that Negative and Positive Distracters generated significantly more negative amplitudes compared to Neutral ones [$p = 0.008$, and $p = 0.005$, respectively]; this result is also depicted in Figure 9 (1). Further, the main effect of Targets was close to significance, but did not manifest any differences between emotional and emotionally neutral pictures; finally, the interaction effect was non-significant.

iv. P3a (418 ms)

No significant main or interaction effects were found for this component.

P3p (418 ms)

Although the main effect of Distracters was nearly significant for the posterior P3 component [$F(2,58) = 3.2$, $p = 0.050$, $\eta^2_p = 0.098$] pointing to larger amplitudes in response to Neutral than Negative Distracters, Bonferroni corrected post-hoc results for this contrast were further away from significance [$p = 0.087$].

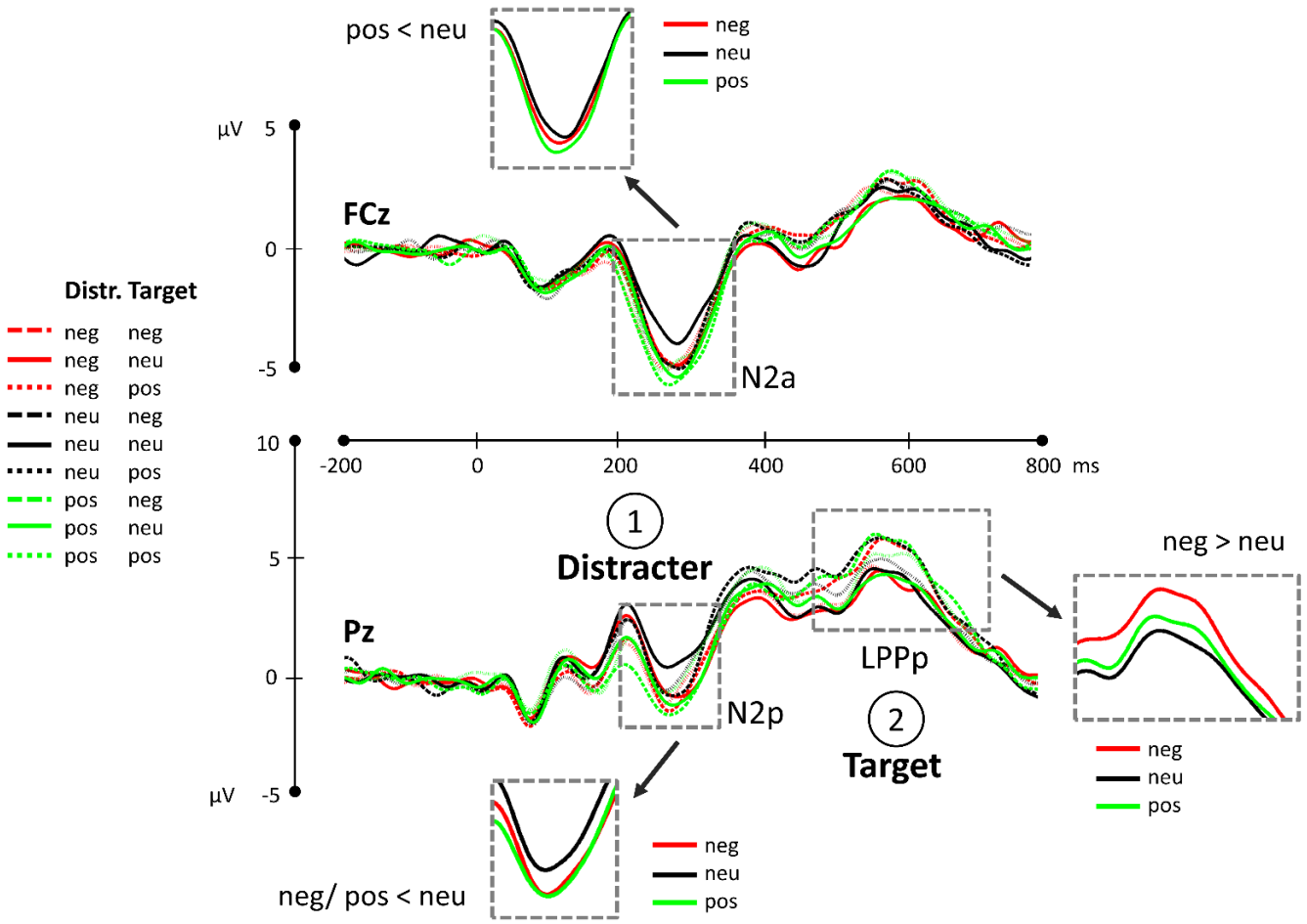


Figure 9.ERP results.Grand averages (depicting all conditions) are shown at FCz and Pz, where the experimental effects may be appreciated. Circled digits represent the temporal sequence of these effects.Significant results at each stage are shown as enlarged detail: 1) Positive Distracters were related to enhanced N2a amplitudes compared to Neutral Distracters, andboth Negative and Positive Distracters were associated with enhanced N2p amplitudes; 2) Negative Targets elicited greater LPPp amplitudes than Neutral Targets.

v. LPPa (581 ms)

No significant main or interaction effects may be reported for LPP at fronto-central sites.

LPPp (581 ms)

In turn, at parieto-occipital scalp regions, there was a main effect of Targets [$F(2,58) = 9.8$, $p < 0.001$, $\eta^2_p = 0.253$], being amplitudes in response to Negative Target pictures larger than to Neutral ones, as confirmed by post-hoc tests [$p < 0.001$]. This result is presented in Figure 9 (2). No more significant main or interaction effects were found.

4.5. Discussion

The present experiment aimed to behaviorally and electrophysiologically explore the competition of endogenous and exogenous attention to emotional pictures through a block design. To this end, a CDTD task was implemented employing both emotional targets and emotional distracters, the former presented in valence-coherent sequences, generating an emotional context. The scope of this block-design was complementing data from Experiment 1 —in which target order was randomized— through a better approach of the experimental conditions to natural situations, and to explore the influence of this approach comparing results from both experiments. Behavioral data obtained in Experiment 1 reflected the attentional bias elicited by emotional targets, and an interaction between the target and distracter content. Further, neural data pointed to a functionally independent course of endogenous and exogenous attention, being the emotional influence serially reflected in the ERP; specifically, amplitudes were modulated by emotional targets at early (N2a) and late (LPPa and LPPp) latencies, and by emotional distracters in between (N2p). For Experiment 2, it was hypothesized that the modified task design would reinforce the outcomes, compared to Experiment 1.

Behavioral indices were sensitive to the emotional content of target pictures, rather than of distracters. Specifically, significantly higher error rates

were found for negative compared to neutral and positive targets. This finding is consistent with the one obtained in Experiment 1, and with previous studies employing indirect tasks (De Cesarei & Codispoti, 2006; Hajcak & Nieuwenhuis, 2006a; Lichtenstein-Vidne et al., 2012). Nevertheless, the interaction effect between target and distracter content observed in reaction times of Experiment 1 was no longer evident in the present experiment, confirming the potential inconsistency of this result, which, as mentioned in the General Discussion section, is opposed to those obtained in previous research.

At the neural level, as expected based on Experiment 1, a significant influence of the emotional content of both targets and distracters was found. Specifically, emotional distracters, relative to neutral ones, prompted increased amplitudes of the N2a and N2p components, whereas, for negative in comparison to neutral targets, greater amplitudes were measured at LPPp. Compared to Experiment 1, the modulatory effects were manifested at a later stage; thus, N2a and N2p peaked at 268 ms, 80 ms later than in Experiment 1, and targets did not significantly show its effect until LPP latencies (581 ms). However, and importantly, effect sizes associated with these results were increased as compared to Experiment 1. The modulatory effect of emotional distracters on N2 —positive versus neutral at anterior scalp regions (N2a), and negative/positive versus neutral at posterior ones (N2p)— is consistent with previous studies, which have also reported significant results for this component at both scalp regions (Buodo et al, 2010; Carretié et al., 2004; Feng et al., 2012); in this previous literature, the advantage of positive valence has also been the most frequent finding at anterior sites, as in the present experiment. Subsequently, the impact of negative targets relative to neutral ones on LPPp —characteristically at parieto-occipital regions— matches with the results of Experiment 1 and with those reported by the two previous electrophysiological studies exploring the same issue at late latencies (MacNamara & Hajcak, 2009; 2010), and by a number of previous studies dealing with endogenous attention to emotional pictures (Bradley et al., 2007; Carretié et al., 2006; Delplanque et al., 2005; Foti et al., 2009; Ito et al., 1998; Keil et al., 2002; O'Hare et al., 2016; Wood & Kisley, 2006). Interestingly, while both emotional

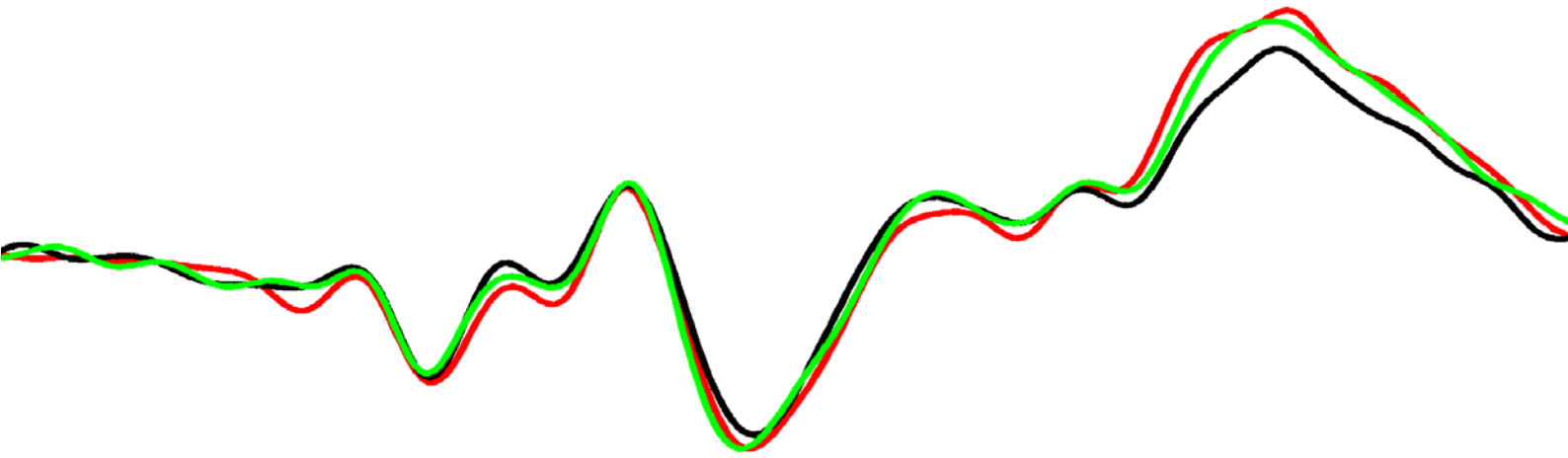
targets and distracters also manifested a marginal influence at earlier latencies, the effect did not reach significance, unlike in Experiment 1. This result might seem contrary to the general enhancement of effects observed in Experiment 2. However, it may be influenced by the predictability inherent to block designs (Carretié, 2016). Thus, since all targets of the same valence were displayed in block, participants could easily predict the emotional content of the next target in the sequence, which may be the reason for the reduced influence elicited by these targets at early latencies. This result will be further discussed in the General Discussion section.

Thus, globally, the block design potentiated exogenous and late endogenous attention effects (except in the early ERP latencies, where the lack of endogenous attention-related effects could be due to predictability). Importantly, it should be noted that the described effects seem to be a consequence of any context, not only of emotional contexts, which is a novel finding and inconsistent with previous literature showing a modulation of attention only for emotional contexts (Cuthbert et al., 1998; Diéguez-Risco et al., 2013; 2015; Domínguez-Borràs et al., 2009; Hietanen & Astikainen, 2013; Ito et al., 1998; Kuniecki et al., 2015; Righart & de Gelder, 2006; 2008a; 2008b; Rothermund et al., 2001; Schupp et al., 2000; Smith et al., 2006; Van Dessel & Vogt, 2012). The lack of interaction between targets and distracters in any component is noteworthy as well. Hence, the reaction time interaction effect observed in Experiment 1 (not observed in error rates) was inconsistent, as confirmed by the lack of behavioral interactions in Experiment 2. At the neural level, both experiments are coherent in favor of a functional segregation of both attentional modalities, at least under the experimental conditions of the present Thesis. In relation to the influence of the valence and arousal dimensions of stimuli, results of Experiment 2 also show broader effects than those obtained in Experiment 1, since, at early latencies, an arousal effect was found along with the valence effect. Hence, the contextual compared to the randomized design seems to favor this early impact of arousal.

In summary, the present results manifest a serial and segregated time course of competing endogenous and exogenous attention, showing an early

modulation by distracters and a late modulation by targets. Earliest effects of the emotional content of targets, as observed in Experiment 1, were not found probably due to the predictability inherent to block designs, but subsequent effects were potentiated, and an additional arousal effect appeared at early stages. Therefore, Experiment 2 confirmed a number of findings reported in Experiment 1, and several of these findings were favored in the present experiment, possibly as a consequence of context. However, other results of Experiment 1 were revealed as being more inconsistent. These similarities and differences between Experiment 1 and Experiment 2 will be addressed again in detail during the General Discussion.

5 DISCUSSION



GENERAL DISCUSSION

The purpose of the present Thesis was to study, through behavioral and ERP indices, concurrent effects of exogenous and endogenous attention to emotional pictures by presenting both kinds of stimuli at the same time during a CDTD paradigm. Specifically, the following objectives were addressed: 1) to explore how the competition between endogenous and exogenous attention is reflected at the behavioral level; 2) to describe the neural time course of the competing attention effects; 3) to analyze how valence and arousal of stimuli modulate this competition; 4) to compare the effects of random and block designs (the latter providing an emotional context) on exogenous and endogenous attention to affective events. Results showed that behavioral data were sensitive to the emotional content of target pictures, rather than to the emotional content of distracters. At the neural level, emotional content of both targets and distracters elicited amplitude modulations of the ERP. The effects appear reflected in the ERP in a serial manner, and seem to occur independently. No clear advantage of the valence or arousal dimensions of pictures was observed. Further, when a context was favored through blocked presentation of emotional targets, the above indicated effects were potentiated. These results are discussed below in detail, organized around each of the objectives of the Thesis.

5.1. Behavioral output of endogenous and exogenous attention competition (objective 1)

In relation to objective 1, previous behavioral evidence on *endogenous* attention has been exclusively obtained from stimulus categorization tasks, since passive viewing paradigms, —the other main paradigm through which this attention modality has been explored—, do not require any behavioral response. Results generally point to a negativity bias: negative pictures have been shown to modulate reaction times and error rates to a greater extent than neutral or even positive ones. The direction of this modulation usually depends on the task-relevance of the emotional information contained in the endogenously attended target pictures. Thus, when emotion is task-relevant (direct tasks), negative pictures seem to increase performance by eliciting faster reaction times and lower error rates than neutral and, in some cases, positive pictures (Hajcak et al., 2006a; Herring et al., 2011; Schupp et al., 2007b; Weinberg et al., 2012; Yuan et al., 2014). Contrarily, negative pictures have been reported to decrease performance through slower reaction times and higher error rates when emotional information is irrelevant for the task (indirect tasks), as in the present study (De Cesarei & Codispoti, 2006; 2011a; Hajcak et al., 2006a). Hence, based on this previous evidence, during the present paradigm it was expected that negative target picture content, rather than neutral or even positive one, would interfere with the behavioral response, eliciting longer reaction times and/or higher error rates. This hypothesis was confirmed by error rates in both Experiment 1 and Experiment 2. Current results are, therefore, consistent with previous data on endogenous attention to emotional stimuli and, interestingly, they are similar to the findings of one of the scarce studies exploring concurrent endogenous and exogenous attention to emotional stimuli at the behavioral level, which has reported worse performance (i.e., longer reaction times) in response to negative targets (Lichtenstein-Vidne et al., 2012).

At the *exogenous* level, previous behavioral evidence has been measured through CDTD tasks, where capture of attentional resources by emotional distracters is reflected in increased reaction times and error rates during the

ongoing task. As in the case of endogenous attention, existing evidence points to a negativity bias: negative distracter pictures seem to worsen performance in the main task to a greater extent than neutral or even positive ones (Buodo et al., 2010; Carretié et al., 2011; 2012; Keil et al., 2005; MacNamara & Hajcak, 2009; 2010; Schönwald & Müller, 2014; Tiferet-Dweck et al., 2016), but there are also studies reporting the highest attentional capture by positive distracters, or by both negative and positive ones (Feng et al., 2012; Müller et al., 2008; 2011). Thus, in the present study, impaired behavioral performance in response to negative or emotional distracters, relative to neutral ones, would have been expected. This outcome would additionally have been in line with the results of the other two studies, which have explored concurrent endogenous and exogenous attention to emotional pictures at the behavioral level (MacNamara & Hajcak, 2009; 2010). However, this hypothesis was not met, since no effects of emotional distracters were observed on behavioral indices. At this respect, an unexpected result found in Experiment 1 was the interaction effect observed for reaction times, where shorter reaction times were detected for emotional compared to neutral targets only when distracters were negative. This effect is inconsistent with the majority of studies reporting worse performance in the presence of negative distracters (Buodo et al., 2010; Carretié et al, 2011; 2012; Keil et al., 2005; MacNamara & Hajcak, 2009; 2010; Schönwald & Müller, 2014; Tiferet-Dweck et al., 2016). Since this effect disappeared in Experiment 2, it should be taken with caution awaiting future evidence.

Therefore, it may be concluded that, when endogenous and exogenous attention compete, as in the present experimental designs, behavioral outputs reflect endogenous, target-related attention. This result is similar to the one reported by Lichtenstein-Vidne et al. (2012), who also reported this emotional influence of targets on behavioral responses to emotional targets and distracters. The fact that, in the present experiments, behavioral indices mainly reflect the impact of emotional targets may be considered as a consequence of the inherent implications of “targets” and “distracters” for behavioral tasks. By definition, targets should necessarily be reflected in behavior, and it might be assumed that

distracter modulation —if observed—, would be an additional but never a sole effect. Actually, MacNamara & Hajcak (2009; 2010) have found an effect of emotional distracters in both reaction times and error rates. However, the task design should be taken into account in order to compare their results with the present ones. Short stimulus presentations, as employed here (i.e., 350 ms), hinder distracters from being endogenously attended, since endogenous attention must be focused on targets to accomplish the task; distracters are only able to exogenously capture attention. Contrarily, longer durations, as employed in the cited studies (i.e., 1000 ms), facilitate later endogenous attention to be directed towards distracters after coping with targets.

5.2. Time course of competing endogenous and exogenous attention processes (objective 2)

Concerning objective 2, ERPs reveal, thanks to their maximal temporal resolution, that competing endogenous and exogenous attention processes seem to take place serially and independently, at least under the present experimental conditions. In Experiment 1, an effect of emotional targets was found at the beginning of the neural response in N2a, at 140 ms, and again at late latencies in LPPa and LPPp, both peaking at 600 ms, whereas emotional distracters prompted larger amplitudes in between these modulations by targets, in N2p, peaking at 182 ms. In Experiment 2, the emotional modulation started with an early effect of distracters in N2a and N2p, at 268 ms. The target effect was prompted at late latencies in LPPp, peaking at 581 ms. These results are in line with previous evidence on endogenous and exogenous attention to emotional stimuli explored separately, and they are also mainly consistent with hypothesis 2.

a) <u>Early effects (<150 ms)</u>

In Experiment 1, an effect of emotional targets was found in N2a, peaking at 140 ms. The amplitude of the N2 family (which involves components with diverse spatial distributions as explained in the Introduction) has been previously

associated with endogenous attention to emotional target pictures (Amrhein et al., 2004; Carretié et al., 2007; Cuthbert et al., 2000; Delplanque et al., 2004; Keil et al., 2001; Palomba et al., 1997), though the component generally has been reported at later latencies (peaking around 250 ms). However, at latencies around 140 ms, as observed here, the same emotional modulation effects have been described for N1 (Foti et al., 2009; Franken et al., 2008; Keil et al., 2002; Yuan et al., 2014). Traditional studies on attention have associated the negative peak around 150 ms with early visual attention to stimuli. Although these early components are mandatory sensory responses to any visual stimulus, they have been reported to present higher amplitudes to voluntarily attended, compared to non-voluntarily attended events (e.g., Hillyard & Anllo-Vento, 1998a; Luck et al., 1994; Mangun, & Hillyard, 1990; see a review in Hillyard, Vogel, & Luck, 1998b). This enhancement is thought to reflect the gain of selective control and the beginning of visual discrimination, and it has been shown that these mechanisms cannot simultaneously occur for stimuli presented at multiple locations (Vogel & Luck, 2000). The early modulation by the emotional content of target pictures around these latencies is therefore compatible with this previous literature. Specifically, the visual system is capable of discriminating stimulus features —as emotional information— around these latency ranges (and even before), but this kind of attention is most probably limited to the endogenously attended location (i.e., the target location). Importantly, in Experiment 2, no early effect of targets was observed.

b) Intermediate effects (150 – 400 ms)

After this early attention to emotional targets in Experiment 1, emotional distracters prompted an effect in N2p (182 ms), which was more pronounced for positive relative to neutral distracter pictures. In Experiment 2, the distracter effect occurred later, at 268 ms, where N2a amplitudes were increased to positive relative to neutral distracters, whereas N2p was more pronounced for both negative and positive distracters. These results are in line with those of previous studies describing a capture bias —especially for positive distracters— in N2a, and

for negative and positive distracters in N2p (Buodo et al, 2012; Carretié et al., 2004; Feng et al., 2012; López-Martín et al., 2013), both usually peaking at approximately 250 ms. Importantly, different members of the N2 family of components have been reported to index automatic attention to deviant stimuli (see a review in Carretié, 2014), but have also been proposed to reflect closely related processes which may have been involved in the present experiments, such as conflict monitoring, detection of novelty and significance, or reorienting (e.g., Berti & Schröger, 2001; Daffner et al., 2000; Kenemans, Verbaten, Melis & Slangen, 1992; Kenemans, Verbaten, Roelofs & Slangen, 1989; see reviews in Folstein & Van Petten, 2008; Pazo-Álvarez, Cadaveira & Amenedo, 2003).

c) Late effects (>400 ms)

Finally, at late latencies, attention was oriented again to emotional targets. In Experiment 1, the emotional content of targets modulated both LPPa and LPPp (600 ms); specifically, in LPPa, negative targets triggered larger amplitudes than neutral ones, and, in LPPp, both negative and positive targets evoked greater amplitudes than neutral ones. In Experiment 2, negative targets elicited higher LPPp (581 ms) amplitudes relative to neutral ones. These results are consistent with a number of previous studies showing an influence of negative (Bradley et al., 2007; Carretié et al., 2006; Delplanque et al., 2005; Foti et al., 2009; Ito et al., 1998; Keil et al., 2002; Wood & Kisley, 2006), or both negative and positive pictures (e.g., Amrhein et al., 2004; Codispoti et al., 2006; 2007; 2009; De Cesarei & Codispoti, 2006; 2011b; Delplanque et al., 2006; Ferrari et al., 2011; 2016; Hajcak et al., 2006a; 2007; Keil et al., 2001; Olofsson & Polich, 2007; Sabatinelli et al., 2007; 2013; Schupp et al., 2003b; 2004a; 2004b; 2013) on LPP. The majority of these effects are maximal at parietal regions, though part of them have also been observed at frontal and occipital sites. In addition, results are in line with those reported by the two previous electrophysiological studies employing a similar task to the one implemented here, which have also detected this emotional LPP effect for targets, compared to distracters (MacNamara & Hajcak, 2009; 2010). In these studies, and due to its long latency, LPP has been interpreted as an index of

sustained endogenous attention (see also Hajcak, MacNamara, & Olvet, 2010 for a review) or an index of recurrent analyses and reappraisal of these stimuli (e.g., Carretié et al., 2006; Hajcak et al., 2006b; Schönfelder et al., 2014). This is consistent with the endogenous–exogenous–endogenous time pattern observed in the present Thesis; thus, after focusing towards distracters at intermediate latencies, attention is directed again to target pictures at LPP latencies, in order to reevaluate the content of these targets.

Importantly, no significant interaction between targets and distracters was found in any ERP component, neither in Experiment 1 nor in Experiment 2. Therefore, it should be concluded that there is no solid neural evidence of a functional interaction between both attentional modalities, at least under the current experimental conditions. Although previous studies (not dealing with emotion) have described largely overlapping endogenous and exogenous attentional networks, some of their elements are only related to a single modality (Corbetta & Shulman, 2002; Corbetta et al., 2008; Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005; Shulman et al., 2010); thus, the inferior frontal gyrus and the temporo-parietal junction —corresponding to the ventral attentional network— have been reported as supporting the exogenous rather than the endogenous modality. Therefore, the present outcome would be mainly in line with this approach. However, it should be emphasized that the conclusions drawn here solely refer to a functional independence circumscribed to particular task demands, given that, in order to infer about structures, source localization analyses would have been needed.

The resulting time course of competing endogenous and exogenous attention revealed by ERP results of Experiment 1 may be explained assuming that, at early stages, participants voluntarily attended where they were told to by task instructions (i.e., the target). However, the distracter rapidly (40 ms later) captured attention thanks to the automatic preattentional monitoring processes mentioned before, which are barely resource consuming and, therefore, are always active in parallel, in order to detect potentially relevant stimuli outside the current attentional focus. Finally, at late latencies, attentional resources were reoriented

again to emotional targets. All these effects were potentiated when stimuli were emotional. Moreover, this time pattern is also consistent with data obtained from steady state potentials exploring the temporal dimension of exogenous attention. These data indicate that processing resources are subtracted from the target before 300 ms and reoriented to the target again after approximately another 300 ms (Müller et al., 2008, 2011; Schönwald & Müller, 2014). Nevertheless, in Experiment 2, early endogenous attention to targets was not observed. This lack of influence of emotional targets at early stages is possibly a consequence of the predictability inherent to block designs. Thus, given that all the targets within the same block were of the same valence, the emotional charge of the next element in the sequence was predictable, which may have reduced the modulation of early attentional correlates. This question will be addressed again in detail when the impact of context is discussed (see 5.4.).

In summary, ERP results of Experiment 1 and Experiment 2 provide evidence on the neural trace of competing endogenous and exogenous attention, which shows a serial time course. While late LPP results replicate previous findings on the same issue, the description of the early ERP time course of competing endogenous and exogenous attention to emotional stimuli is novel, since the present study is the first one which explores this question at early latencies. The present data suggest that, at least under the current experimental conditions, a functional segregation of endogenous and exogenous attention may occur, since no significant interaction effects were observed.

5.3. The influence of valence and arousal of targets and distracters on competing endogenous and exogenous attention (objective 3)

In relation to objective 3, it may be concluded that a negativity bias was prevalent at the behavioral level in both experiments, whereas a variable pattern —as a function of time—of valence and arousal modulation was observed at the neural level; specifically, ERPs uncovered valence effects at early latencies and arousal effects at late latencies in Experiment 1, while, in Experiment 2, an additional arousal effect was observed along with the valence effect at early stages, and, at

late stages, the pattern was inverted, showing an influence of valence instead of arousal. During the following section, these results will be discussed in detail.

a) Behavioral results

The negativity bias observed for behavioral indices in both experiments is in line with hypothesis 3 and with the majority of previous results. Thus, it seems that, at the behavioral level, only the most urgent picture content is addressed (in evolutionary terms, negative events may be assumed as more urgent than neutral or even positive ones because of the potentially more dramatic consequences associated with ignoring or reacting slowly to them; Ekman, 1992; Öhman, Hamm, & Hugdahl, 2000). This finding may be due to behavior being the single final output of a complex set of neural processes. According to the present results, these neural processes in fact are sensitive to the influence of both valence and arousal, and within valence, to negative and positive; but during the final behavioral response, which is crucial from an adaptive point of view, the most urgent (i.e., negative) events are prioritized.

b) Neural results

Concerning neural data of *Experiment 1*, it may be concluded that, as expected in hypothesis 3, valence prevailed at early latencies, while arousal influenced late amplitudes to a greater extent. This late outcome is in line with a large body of previous findings reporting this arousal effect (e.g., Amrhein et al., 2004; Codispoti et al., 2006; 2007; 2009; De Cesarei & Codispoti, 2006; 2011b; Delplanque et al., 2006; Ferrari et al., 2011; 2016; Hajcak et al., 2006a; 2007; Keil et al., 2001; Olofsson & Polich, 2007; Sabatinelli et al., 2007; 2013; Schupp et al., 2003b; 2004a; 2004b; 2013). In contrast, at earlier processing stages, previous results are variable. In Experiment 1, endogenous attention to targets manifested a negativity bias, whereas exogenous attention to distracters showed a positivity offset. Previous evidence concerning endogenous attention to emotional stimuli does not indicate a clear bias in favor of negative or positive stimuli at early latencies, but

the present data are consistent with those studies reporting a preference towards negative pictures at early stages of processing (Delplanque et al., 2004; Carretié et al., 2001a; 2001b; 2006; 2007; Huang & Luo, 2007, Olofsson & Polich, 2007; Yuan et al., 2014). This result may also be related to the task employed in this study; in fact, a negativity bias in the same component (N2) has been previously reported only when participants were engaged in a stimulus categorization task, similar to the present one, but not when they were asked to passively view the pictures (Carretié et al., 2007; Delplanque et al., 2004). In turn, literature on exogenous attention preferentially shows a bias towards negative stimulation, but this may be due to the scarce number of studies employing positive —apart from negative— distracter pictures. However, in N2, the advantage of positive distracters has also been the most frequent result in previous works (Carretié et al., 2004; Feng et al., 2012), though sometimes together with an even earlier influence of negative distracters (Carretié et al., 2004), which is absent in the present results. This may be because attentional resources were devoted to the emotional content of targets at this time point (unlike in the above mentioned studies where targets were neutral), so that this first modulation of negative distracters was not reflected in the ERP, due to a competition between emotional targets and distracters. Nevertheless, it should be noted that the present experimental design is different from the previous ones cited above, given that none of these studies analyzed the competition of endogenous and exogenous attention to emotional stimuli; thus, present and existing findings should be compared with caution.

With respect to neural data of *Experiment 2*, it may be observed that results partially diverge from hypothesis 3 and from those of Experiment 1. Thus, both valence and arousal affected N2 amplitudes, while only valence influenced the LPP (hypothesis 3 predicted a modulation of valence at early stages and of arousal at later stages of processing). As indicated, literature on exogenous attention employing positive pictures is scarce and most studies did not combine negative and positive distracter pictures during the same experiment, in comparison with neutral ones. The limited number of previous studies have reported, on the one hand, a preference of negative distracters, relative to neutral ones, reflected in N2p

(Buodo et al., 2012), and other earlier components (i.e., P1p, P2a; Carretié et al., 2004; 2012), and, on the other hand, of positive distracters in N2a (Carretié et al., 2004; Feng et al., 2012). However, there are no studies showing a simultaneous advantage of both negative and positive distracters, compared to neutral ones, associated with the N2 family of components. Nevertheless, as noted above, previous studies did not take into account the competition between endogenous and exogenous attention to emotional stimuli, so that present and existing findings are not directly comparable; and a potential effect of this competition may actually be the particular pattern of valence modulation observed here. Finally, the LPPp result, indicating an advantage of negative relative to neutral targets, is in line with several previous studies (Bradley et al., 2007; Carretié et al., 2006; Delplanque et al., 2005; Foti et al., 2009; Ito et al., 1998; Keil et al., 2002; O'Hare et al., 2016; Wood & Kisley, 2006), but not with those showing the most frequently observed arousal effect (see a review in Olofsson et al., 2008). Here, amplitudes in response to positive targets were indeed higher than in response to neutral ones, but the difference did not reach significance, indicating that the modulation by positive targets was smaller than in other studies. One reasonable explanation derives from the results of Wiens et al. (2011) and Wiens & Syrjänen (2013), who have reported a reduction of LPP amplitudes in response to positive pictures when attention was directed away from the pictures. This evidence might be extrapolated to the present study, in which attention was also withdrawn from the target (due to the presentation of distracters). However, this approach would contradict the arousal effect which was actually observed in Experiment 1. Hence, the reason is most probably related to the context generated in Experiment 2, which made the valence of the next target in the sequence predictable, as will be discussed in detail during the following section (see 5.4.).

In summary, in Experiment 1, a modulatory influence of valence was observed at early latencies and of arousal at late latencies, in line with the hypothesis and with the majority of previous results concerning endogenous and exogenous attention to emotional stimuli separately. In turn, in Experiment 2, an additional arousal effect appeared along with the valence effect at early stages of

processing, whereas valence instead of arousal influenced the ERPs at later stages, most probably due to the impact of the contextual design addressed next.

5.4. Influence of the random versus block (contextual) design on endogenous-exogenous attention competition (objective 4)

Experiment 1 of this Thesis employed a paradigm in which emotional and neutral targets and distracters were combined in a fully randomized manner, following the most common experimental procedure used in this field of research. In contrast, in Experiment 2, the presentation of emotional conditions of targets was blocked, in order to generate affective contexts and to increase ecological validity of the task. The fourth objective of this Thesis was to explore the consequences of manipulating these task settings, and it was expected that experimental effects would be potentiated due to this factor. Differences were actually observed, providing evidence for hypothesis 4.

At the behavioral level, results of Experiment 1 and Experiment 2 are very similar, showing a main effect of targets on error rates. Thus, the behavioral output during competing endogenous and exogenous attention to emotional stimuli does not seem to be influenced by the emotional context generated in Experiment 2.

At the neural level, in Experiment 2 compared to Experiment 1, emotional distracters seem to have influenced N2 amplitudes 80 ms later than in Experiment 1, though time difference between experiments should be interpreted with caution due to differences in the task design. The late endogenous LPP effect occurred at similar latencies in both experiments, but the modulating influence of positive targets on LPPp amplitude disappeared in Experiment 2. Nevertheless, when comparing effect sizes of the observed results, it may be concluded that the N2 and LPP effects[6] elicited under the context in Experiment 2 were actually much larger than those of Experiment 1: the effect size of N2p increased by 38% (η^2_p= 0.147 versus η^2_p= 0.203, respectively), while the effect size of LPPp augmented by 74% (η^2_p= 0.145 versus η^2_p= 0.253, respectively). Moreover, in Experiment 2, an

[6]Only the experimental effects common to both experiments may be compared.

additional arousal effect was observed along with the valence effect (also observed in Experiment 1) at early latencies (N2). Hence, it seems that the contextual compared to the randomized design potentiated exogenous and late endogenous attention to emotional information. Previous studies exploring the influence of context on attention to emotional pictures have shown that emotional (negative and/or positive) but not neutral contexts may broaden attention (Cuthbert et al., 1998; Domínguez-Borràs et al., 2009; Diéguez-Risco et al., 2013, 2015; Hietanen & Astikainen, 2013; Ito et al., 1998; Kuniecki et al., 2015; Righart & de Gelder, 2006, 2008a, 2008b; Rothermund et al., 2001; Schupp et al., 2000; Smith et al., 2006; Van Dessel & Vogt, 2012). Further, affective compared to neutral moods have also been proposed to be able to alter attention (Carboni et al., under review; Chen et al., 2008; MacNamara & Hajcak, 2010; Melcher et al., 2011; Moriya & Nittono, 2011; Rokke & Lystad, 2015; Rossi & Pourtois, 2012, in press; Vanlessen et al., 2013, 2014; Wadlinger & Isaacowitz, 2006; Yuan et al., 2014). However, these approaches are inconsistent with the present finding, since current effects occurred during both emotional and neutral contexts and were, therefore, independent from valence or arousal of the context.

Emotional targets did not significantly show their effect until LPP latencies, while in Experiment 1 target impact was evident very early at about 150 ms, even before the distracter effect. Certainly, both emotional targets and distracters also manifested a marginally influence at earlier latencies, but the effect did not reach significance, unlike in Experiment 1. The fact that early attention to emotional targets was not potentiated by the context, unlike later effects, may be a mere consequence of the predictability inherent to block designs; thus, as all targets within the same block were of similar valence, the emotional charge of the next element in the sequence was easily to guess, which may have weakened early effects at the endogenous attention level. This interpretation is supported by previous ERP literature employing neutral stimulation (letters), which reported that target stimuli embedded in a predictable context prompted decreased N2 amplitudes (Nigbur, Schneider, Sommer, Dimigen, & Stürmer, 2015). It is also in line with fMRI data showing that increased expectation of a target stimulus will

reduce neural activity in visual regions representing the stimulus, compared to non-expected stimuli (Summerfield & Egner, 2009).

In conclusion, random and blocked (contextual) conditions caused differential effects in competing endogenous and exogenous attention. Thus, an attempt to approach a real situation might possibly affect the outcomes of a study; specifically, in line with the hypothesis, as a consequence of context, the power of the experimental design to detect an effect appeared to be increased, thus, exogenous effects at early (N2) and endogenous effects at late (LPP) latencies were enhanced, compared to the random design. Moreover, an additional influence of arousal was measured, not only at late latencies reflecting endogenous results, but also at earlier stages related to exogenous attention (N2). This confirms that emotional effects on attention increase as experimental designs approach, at least partially, real life situations. However, the initial index of endogenous attention to emotional pictures observed during random presentation disappeared when a context was generated, showing that —at initial stages— effects may be reduced probably due to the predictability associated with the block design.

5.5. Limitations and future directions

In relation to the operationalization of the context, it might be emphasized that, in Experiment 2, emotional contexts were generated by presenting emotional targets in a block-design fashion. For the reasons explained in the Methods section, picture sets of the same valence category were composed of stimuli from a variety of distinct thematic categories, which were randomly shown during the same emotional block. However, an approximation to a real context would perhaps have been maximized by pictures from a single affective motif (e.g., all threatening animals, or all erotic scenes), which would have resembled a particular situation, and results from such a task would have been generalized even better to non-laboratory scenarios. Importantly, in this case, subclassifications of both negative and positive stimuli —beyond the two-dimensional valence × arousal space— should also be taken into account, given that effects may vary employing one particular stimulus content or another. Thus, fearful and disgusting pictures may

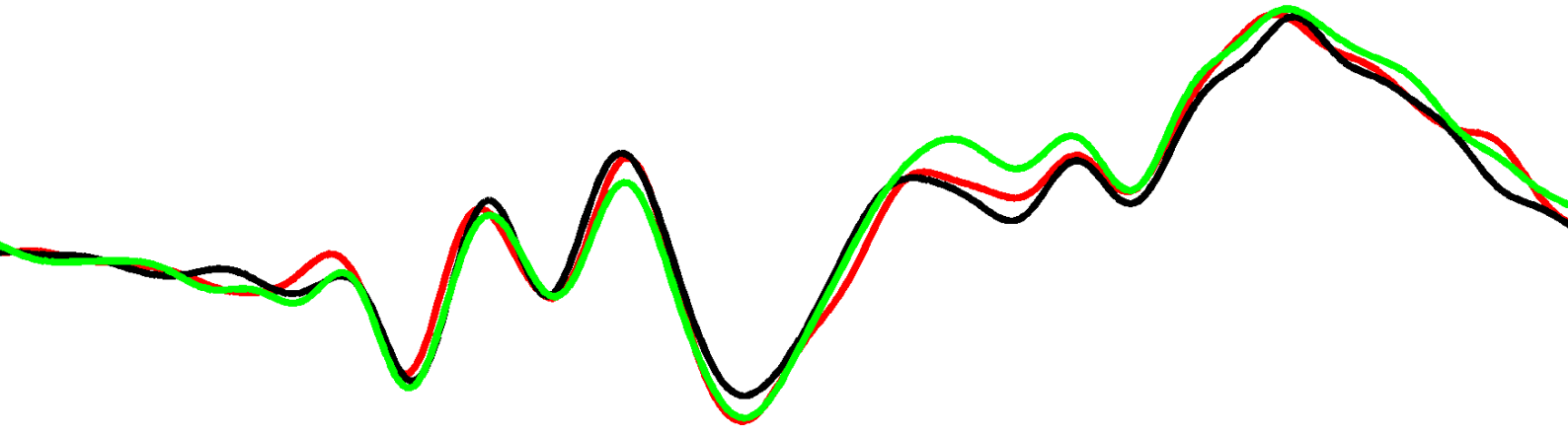
be further differentiated at both the behavioral and neural level, showing an advantage of disgusting information (Carretié et al., 2011; Van Hooff, Devue, Vieweg, & Theeuwes, 2013). Moreover, certain stimuli related to specific fears or phobias may elicit enhanced behavioral and neural attention correlates, as compared to other unpleasant stimuli (Buodo et al., 2010). On the other hand, there are also data showing increased attention to sexually-loaded pictures, with respect to other positive stimuli (Feng et al., 2012; Schupp et al., 2000; 2004b). The influence of a single affective category (e.g., threatening animals, household objects, and erotic scenes) generating the context should therefore be analyzed in future studies. Importantly, the same motif should be presented in a random and in a block design, in order to be able to compare the effects.

Moreover, there are several other factors which might possibly be relevant to the question on issue and which, therefore, might be considered in future studies addressing competing endogenous and exogenous attention to emotional pictures. First, it may be mentioned that target and distracter pictures sizes were different, being target pictures smaller than distracter pictures. It has been previously reported that a reduction of picture size lowers emotional effects at early latencies, while it does not affect emotional LPP results (De Cesarei & Codispoti, 2006; 2011b), so that, during the present study, given the relatively small picture sizes, early effects of targets may have been minimized compared to distracter effects and compared to effects reported by others studies. Hence, in a potential future study, target size might be increased. Second, another variable, which may have shown an impact on target effects, is stimulus duration. Specifically, the lack of LPP amplitude differences between positive and neutral target pictures discussed above may be related to the particular exposure duration. Indeed, recent data indicate that duration of endogenously attended pictures may cause valence differences at LPP latencies (Kessel, Tapia, Hoyos, Capilla, & Carretié, in preparation). Thus, a future study on the same issue might present the pictures during several (shorter and longer) durations. A third factor, which might be modulated in the future, is task-relevance of the emotional content of targets. Although results obtained for both task-relevant and task-irrelevant

emotional picture contents are very similar at the neural level when endogenous attention is analyzed separately (Schupp et al., 2006a), effects on competing endogenous and exogenous attention might vary with an emphasis on the emotional content of targets.

Finally, future studies should also provide source localization data, in order to determine which attentional stage is reflected in each of the components showing significant effects; in fact, it would be especially interesting to differentiate between the components of exogenous attention (i.e., preattention, reorientation, and sensory amplification). Moreover, source localization would be needed in order to further explore—in spatial terms— the question concerning the functional independence of both attentional modalities.

6 CONCLUSIONS/ CONCLUSIONES



GENERAL CONCLUSIONS

The present Thesis explored, through behavioral and electrophysiological measures, concurrent endogenous and exogenous attention to emotional stimuli under experimental designs leading to a competition between both modalities. In Experiment 1, emotional pictures were randomly presented as both targets and distracters, while, in Experiment 2, emotional categories of targets were administered in blocks, in order to better approach a real situation. Based on the results obtained from these experiments, the following conclusions may be drawn:

1) Behavioral indices recorded during competing endogenous and exogenous attention to emotional stimuli were sensitive to the emotional content of targets, rather than of distracters, as evidenced by higher error rates in response to negative, compared to neutral and positive targets (Experiment 1 & 2).
2) At the neural level, significant modulatory effects of the emotional content of both targets and distracters were observed. The effects were serially reflected in the ERP time course, beginning with an influence of emotional targets at early latencies (Experiment 1), switching to emotional distracters (Experiment 1 & 2), and finally to emotional targets at late latencies (Experiment 1 & 2). Contrasts regarding the interaction between emotional

target and distracter effects did not reach significance, suggesting a functional independence of both processes, at least under the current experimental designs.

3) A valence effect (negativity bias) dominated at the behavioral level (Experiment 1 & 2), whereas neural data detected both valence and arousal effects. In Experiment 1, valence effects were patent at early latencies and arousal effects at late latencies, while, in Experiment 2, an additional arousal effect was observed along with the valence effect at early stages of processing; in turn, at late stages, valence was prioritized.
4) At the behavioral level, both the random and the contextual design yielded similar effects. At the neural level, as a consequence of context, indices of exogenous attention towards distracters and late endogenous attention towards targets were enhanced. Moreover, the influence of arousal on exogenous attention was potentiated by the context. Merely, initial endogenous attention to targets was inhibited during the context.

CONCLUSIONES GENERALES

La presente Tesis exploró, a través de medidas conductuales y electrofisiológicas, la atención endógena y exógena simultánea a estímulos emocionales, bajo un diseño experimental que daba lugar a la competición entre ambas modalidades. En el Experimento 1, se presentaron escenas emocionales como estímulo objetivo y estímulo distractor de forma aleatoria, mientras que, en el Experimento 2, las categorías de los objetivos fueron administrados en bloque, con el fin de regenerar una situación real. En base a los resultados obtenidos en esos experimentos, se puede concluir lo siguiente:

1) Los índices conductuales registrados mientras que la atención endógena y exógena estaban competiendo resultaron ser sensibles al contenido de los objetivos pero no de los distractores, lo cual se vio reflejado en una mayor tasa de error ante objetivos negativos, en comparación con objetivos neutros y positivos.
2) A nivel neural, se observaron efectos moduladores significativos, tanto para estímulos objetivos como para distractores. Los efectos se manifestaron de manera serial en el curso temporal del PER, empezando por la influencia de estímulos objetivo emocionales a latencias tempranas (Experimento 1), cambiando a distractores emocionales (Experimento 1 & 2), y finalmente a

objetivos emocionales a latencias tardías (Experimento 1 & 2). Los contrastes sobre la interacción entre objetivos y distractores emocionales no llegaron a ser significativos, sugiriendo una independencia funcional entre ambos procesos, al menos bajo las condiciones experimentales presentes.

3) Un efecto de la valencia (sesgo de negatividad) predominó a nivel conductual, mientras que los datos neurales detectaron efectos tanto de valencia como de arousal. En el Experimento 1, los efectos de valencia fueron encontrados a latencias tempranas y los efectos de arousal a latencias tardías, mientras que, en el Experimento 2, un efecto adicional de arousal fue observado junto al efecto de valencia en momentos tempranos de procesamiento; en cambio, en momentos tardíos, la valencia se vio priorizada.
4) A nivel conductual, el diseño aleatorio y el diseño contextual dieron lugar a efectos similares. A nivel neural, como consecuencia del contexto, los índices reflejando la atención exógena hacia distractores y la atención endógena tardía hacia objetivos fueron elevados. Asimismo, la influencia del arousal sobre la atención exógena fue potenciada por el contexto. Solamente la atención endógena inicial a estímulos objetivo fue inhibida durante el contexto.

LIST OF ABREVIATIONS

a	Anterior
ANOVA	Analysis of variance
CDTD	Concurrent but distinct target-distracter task
EEG	Electroencephalogram
EOG	Electrooculogram
EPN	Early posterior negativity
ERP	Event related potential
LPP	Late positive potential
Neg	Negative
Neu	Neutral
p	Posterior
PCA	Principal component analysis
Pos	Positive
PSW	Positive slow wave
SF	Spatial factor
sPCA	Spatial principal component analysis
TF	Temporal factor
tPCA	Temporal principal component analysis

REFERENCES

Adolphs, R. (2004). Emotional vision. *Nature Neuroscience, 7,* 1167–1168.

Alorda, C., Serrano-Pedraza, I., Campos-Bueno, J. J., Sierra-Vázquez, V., & Montoya, P. (2007). Low spatial frequency filtering modulates early brain processing of affective complex pictures. *Neuropsychologia, 45(14),* 3223-3233.

Amrhein, C., Mühlberger, A., Pauli, P., & Wiedemann, G. (2004). Modulation of event-related brain potentials during affective picture processing: a complement to startle reflex and skin conductance response? *International Journal of Psychophysiology, 54(3),* 231-240.

Bar, M. (2003). A cortical mechanism for triggering top-down facilitation in visual object recognition. *Journal of Cognitive Neuroscience, 15(4),* 600-609.

Bar, M., Kassam, K. S., Ghuman, A. S., Boshyan, J., Schmid, A. M., Dale, A. M., Hämäläinen, M. S., Marinkovic, K., Schacter, D. L., Rosen, B. R., & Halgren, E. (2006). Top-down facilitation of visual recognition. *Proceedings of the National Academy of Sciences of the United States of America, 103(2),* 449-454.

Bediou, B., Eimer, M., d'Amato, T., Hauk, O., & Calder, A. J. (2009). In the eye of the beholder: Individual differences in reward-drive modulate early frontocentral ERPs to angry faces. *Neuropsychologia, 47(3),* 825-834.

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8(6),* 551-565.

Bernat, E. M., Cadwallader, M., Seo, D., Vizueta, N., & Patrick, C. J. (2011). Effects of instructed emotion regulation on valence, arousal, and attentional measures of affective processing. *Developmental Neuropsychology, 36(4),* 493-518.

Berti, S., & Schröger, E. (2001). A comparison of auditory and visual distraction effects: behavioral and event-related indices. *Cognitive Brain Research, 10(3),* 265-273.

Blechert, J., Sheppes, G., Di Tella, C., Williams, H., & Gross, J. J. (2012). See what you think. Reappraisal modulates behavioral and neural responses to social stimuli. *Psychological Science,* 0956797612438559.

Bradley, M. M., Hamby, S., Löw, A., & Lang, P. J. (2007). Brain potentials in perception: picture complexity and emotional arousal. *Psychophysiology, 44(3),* 364-373.

Brainard, D. H. (1997) The Psychophysics Toolbox, *Spatial Vision, 10*, 433-436.

Britton, J. C., Taylor, S. F., Sudheimer, K. D., & Liberzon, I. (2006). Facial expressions and complex IAPS pictures: common and differential networks. *Neuroimage, 31(2),* 906-919.

Bublatzky, F., Gerdes, A., White, A. J., Riemer, M., & Alpers, G. W. (2014). Social and emotional relevance in face processing: happy faces of future interaction partners enhance the late positive potential. *Frontiers in Human Neuroscience, 8,* 493.

Buodo, G., Sarlo, M., & Munafò, M. (2010). The neural correlates of attentional bias in blood phobia as revealed by the N2pc. *Social, Cognitive, & Affective Neuroscience, 5(1),* 29-38.

Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1999). The affect system has parallel and integrative processing components: Form follows function. *Journal of Personality and Social Psychology, 76(5),* 839.

Calvo, M. G., & Nummenmaa, L. (2011). Time course of discrimination between emotional facial expressions: The role of visual saliency. *Vision Research, 51(15),* 1751-1759.

Carboni, A., Kessel, D., Capilla, A., & Carretié, L. (under review). The influence of affective state on exogenous attention to emotional distractors: Behavioral and neural data. *Social, Cognitive, & Affective Neuroscience.*

Carretié, L. (2014). Exogenous (automatic) attention to emotional stimuli: a review. *Cognitive, Affective, & Behavioral Neuroscience, 14(4),* 1228-1258.

Carretié, L. (2016). Anatomía de la mente (2nd Ed.). Madrid: Pirámide.

Carretié, L., Albert, J., López-Martín, S., Hoyos, S., Kessel, D., Tapia, M., & Capilla, A. (2013). Differential neural mechanisms underlying exogenous attention to peripheral and central distracters. *Neuropsychologia, 51(10),* 1838-1847.

Carretié, L., Kessel, D., Carboni, A., López-Martín, S., Albert, J., Tapia, M., Mercado, F., Capilla, A., & Hinojosa, J. A. (2012). Exogenous attention to facial vs non-facial emotional visual stimuli. *Social, Cognitive, & Affective Neuroscience, 8,* 764-773.

Carretié, L., Hinojosa, J. A., Albert, J., & Mercado, F. (2006). Neural response to sustained affective visual stimulation using an indirect task. *Experimental Brain Research, 174(4),* 630-637.

Carretié, L., Hinojosa, J. A., López-Martín, S., Albert, J., Tapia, M., & Pozo, M. A. (2009). Danger is worse when it moves: Neural and behavioral indices of enhanced attentional capture by dynamic threatening stimuli. *Neuropsychologia, 47(2),* 364-369.

Carretié, L., Hinojosa, J. A., López-Martín, S., & Tapia, M. (2007). An electrophysiological study on the interaction between emotional content and spatial frequency of visual stimuli. *Neuropsychologia, 45(6),* 1187-1195.

Carretié, L., Hinojosa, J. A., Martín-Loeches, M., Mercado, F., & Tapia, M. (2004). Automatic attention to emotional stimuli: neural correlates. *Human Brain Mapping, 22(4),* 290-299.

Carretié, L., Hinojosa, J.A., Mercado, F., & Tapia, M. (2005). Cortical response to subjectively unconscious danger. *Neuroimage 24,* 615–623.

Carretié, L., Martín-Loeches, M., Hinojosa, J. A., & Mercado, F. (2001a). Emotion and attention interaction studied through event-related potentials. *Journal of Cognitive Neuroscience, 13(8),* 1109-1128.

Carretié, L., Mercado, F., Tapia, M., & Hinojosa, J. A. (2001b). Emotion, attention, and the 'negativity bias', studied through event-related potentials. *International Journal of Psychophysiology, 41(1),* 75-85.

Carretié, L., Ríos, M., Periáñez, J. A., Kessel, D., & Álvarez-Linera, J. (2012). The role of low and high spatial frequencies in exogenous attention to biologically salient stimuli. *PLoS One, 7(5),* e37082.

Carretié, L., Ruiz-Padial, E., López-Martín, S., & Albert, J. (2011). Decomposing unpleasantness: Differential exogenous attention to disgusting and fearful stimuli. *Biological Psychology, 86(3),* 247-253.

Catani, M., & de Schotten, M. T. (2008). A diffusion tensor imaging tractography atlas for virtual in vivo dissections. *Cortex, 44(8),* 1105-1132.

Chai, H., Chen, W. Z., Zhu, J., Xu, Y., Lou, L., Yang, T., He, W., & Wang, W. (2012). Processing of facial expressions of emotions in healthy volunteers: an exploration with event-related potentials and personality traits. *Clinical Neurophysiology, 42(6),* 369-375.

Chammat, M., Foucher, A., Nadel, J., & Dubal, S. (2010). Reading sadness beyond human faces. *Brain Research, 1348,* 95-104.

Chapman, C., Hoag, R., & Giaschi, D. (2004). The effect of disrupting the human magnocellular pathway on global motion perception. *Vision Research, 44,* 2551– 2557.

Chapman, R. M., & McCrary, J. W. (1995). EP component identification and measurement by principal components analysis. *Brain & Cognition, 27,* 288–310.

Chen, J., Yuan, J., Huang, H., Chen, C., & Li, H. (2008). Music-induced mood modulates the strength of emotional negativity bias: An ERP study. *Neuroscience Letters, 445(2),* 135-139.

Clark, V. P., Fan, S., & Hillyard, S. A. (1994). Identification of early visual evoked potential generators by retinotopic and topographic analyses. *Human Brain Mapping, 2(3),* 170-187.

Cliff, N. (1987). *Analyzing multivariate data.* San Diego, CA: Harcourt Brace Jovanovich.

Cloitre, M. (1992) *The avoidance of emotional processing: A cognitive science perspective.* In D. J. Stein & J. E. Young (Eds.), Cognitive science and clinical disorders (pp. 20–40). Orlando, FL: Academic Press.

Codispoti, M., Ferrari, V., & Bradley, M. M. (2006). Repetitive picture processing: autonomic and cortical correlates. *Brain Research, 1068(1),* 213-220.

Codispoti, M., Ferrari, V., & Bradley, M. M. (2007). Repetition and event-related potentials: distinguishing early and late processes in affective picture perception. *Journal of Cognitive Neuroscience, 19(4),* 577-586.

Codispoti, M., Mazzetti, M., & Bradley, M. M. (2009). Unmasking emotion: exposure duration and emotional engagement. *Psychophysiology, 46(4),* 731-738.

Conroy, M. A., & Polich, J. (2007). Affective valence and P300 when stimulus arousal level is controlled. *Cognition and Emotion, 21(4),* 891-901.

Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: from environment to theory of mind. *Neuron, 58(3),* 306-324.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews of Neuroscience, 3(3),* 201-215.

Conty, L., Dezecache, G., Hugueville, L., & Grèzes, J. (2012). Early binding of gaze, gesture, and emotion: neural time course and correlates. *The Journal of Neuroscience, 32(13),* 4531-4539.

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. *Biological Psychology, 52(2),* 95-111.

Cuthbert, B. N., Schupp, H. T., Bradley, M., McManis, M., & Lang, P. J. (1998). Probing affective pictures: Attended startle and tone probes. *Psychophysiology, 35(03),* 344-347.

Daffner, K. R., Mesulam, M. M., Scinto, L. F., Calvo, V., Faust, R., & Holcomb, P. J. (2000). An electrophysiological index of stimulus unfamiliarity. *Psychophysiology, 37(6),* 737-747.

Dan-Glauser, E. S., & Scherer, K. R. (2011). The Geneva affective picture database (GAPED): a new 730-picture database focusing on valence and normative significance. *Behavior Research Methods, 43(2),* 468-477.

De Cesarei, A., & Codispoti, M. (2006). When does size not matter? Effects of stimulus size on affective modulation. *Psychophysiology, 43(2),* 207-215.

De Cesarei, A., Codispoti, M., & Schupp, H. T. (2009). Peripheral vision and preferential emotion processing. *Neuroreport, 20(16),* 1439-1443.

De Cesarei, A., & Codispoti, M. (2011a). Scene identification and emotional response: which spatial frequencies are critical? *Journal of Neuroscience, 31(47),* 17052-17057.

De Cesarei, A., & Codispoti, M. (2011b). Affective modulation of the LPP and α-ERD during picture viewing. *Psychophysiology, 48(10),* 1397-1404.

De Fockert, J., Rees, G., Frith, C., & Lavie, N. (2004). Neural correlates of attentional capture invisual search. *Journal of Cognitive Neuroscience, 16,* 751-759.

Delplanque, S., Lavoie, M. E., Hot, P., Silvert, L., & Sequeira, H. (2004). Modulation of cognitive processing by emotional valence studied through event-related potentials in humans. *Neuroscience Letters, 356(1),* 1-4.

Delplanque, S., Silvert, L., Hot, P., & Sequeira, H. (2005). Event-related P3a and P3b in response to unpredictable emotional stimuli. *Biological Psychology, 68(2),* 107-120.

Delplanque, S., Silvert, L., Hot, P., Rigoulot, S., & Sequeira, H. (2006). Arousal and valence effects on event-related P3a and P3b during emotional categorization. *International Journal of Psychophysiology, 60(3),* 315-322.

Del Zotto, M., & Pegna, A. J. (2015). Processing of masked and unmasked emotional faces under different attentional conditions: an electrophysiological investigation. *Frontiers in Psychology,* 6.

Diéguez-Risco, T., Aguado, L., Albert, J., & Hinojosa, J. A. (2013). Faces in context: Modulation of expression processing by situational information. *Social Neuroscience, 8(6),* 601-620.

Diéguez-Risco, T., Aguado, L., Albert, J., & Hinojosa, J. A. (2015). Judging emotional congruency: Explicit attention to situational context modulates processing of facial expressions of emotion. *Biological Psychology, 112,* 27-38.

Di Russo, F., Martínez, A., Sereno, M. I., Pitzalis, S., & Hillyard, S. A. (2002). Cortical sources of the early components of the visual evoked potential. *Human Brain Mapping, 15(2),* 95-111.

Dien, J. (2010). Evaluating two step PCA of ERP data with geomin, infomax, oblimin, promax, and varimax rotations. *Psychophysiology, 47,* 170–83.

Dien, J. (2012). Applying principal components analysis to event-related potentials: a tutorial. *Developmental Neuropsychology, 37(6),* 497-517.

Dien, J., Beal, D. J., & Berg, P. (2005). Optimizing principal components analysis of event-related potentials: matrix type, factor loading weighting, extraction, and rotations. *Clinical Neurophysiology, 116(8),* 1808-1825.

Dien, J., Khoe, W., & Mangun, G. R. (2007). Evaluation of PCA and ICA of simulated ERPs: Promax vs. Infomax rotations. *Human Brain Mapping, 28(8),* 742-763.

Dien, J., Tucker, D. M., Potts, G., & Hartry-Speiser, A. (1997). Localization of auditory evoked potentials related to selective intermodal attention. *Journal of Cognitive Neuroscience, 9(6),* 799-823.

Dolcos, F., & Cabeza, R. (2002). Event-related potentials of emotional memory: encoding pleasant, unpleasant, and neutral pictures. *Cognitive, Affective, & Behavioral Neuroscience, 2(3),* 252-263.

Domínguez-Borràs, J., Trautmann, S. A., Erhard, P., Fehr, T., Herrmann, M., & Escera, C. (2009). Emotional context enhances auditory novelty processing in superior temporal gyrus. *Cerebral Cortex, 19(7),* 1521-1529.

Duncan-Johnson, C. C., & Donchin, E. (1977). On quantifying surprise: The variation of event-related potentials with subjective probability. *Psychophysiology, 14(5),* 456-467.

Egner, T., Etkin, A., Gale, S., & Hirsch, J. (2008). Dissociable neural systems resolve conflict from emotional versus nonemotional distracters. *Cerebral Cortex, 18(6)*, 1475-1484.

Eimer, M. (1996). The N2pc component as an indicator of attentional selectivity. *Electroencephalography and Clinical Neurophysiology, 99(3),* 225-234.

Eimer, M., & Kiss, M. (2007). Attentional capture by task-irrelevant fearful faces is revealed by the N2pc component. *Biological Psychology, 74(1),* 108-112.

Ekman, P.(1992). An argument for basic emotions. *Cognition & Emotion, 6,* 169–200.

Emery, N. J., & Amaral, D. G. (2000). *The role of the amygdala in primate social cognition.* In R. D. Lane, & L. Nadel (Eds.). Cognitive Neuroscience of Emotion (pp. 156–191). New York: Oxford University Press.

Feng, C., Wang, L., Wang, N., Gu, R., & Luo, Y. J. (2012). The time course of implicit processing of erotic pictures: An event-related potential study. *Brain Research, 1489,* 48-55.

Ferrari, V., Bradley, M. M., Codispoti, M., & Lang, P. J. (2011). Repetitive exposure: brain and reflex measures of emotion and attention. *Psychophysiology, 48(4),* 515-522.

Ferrari, V., Codispoti, M., Cardinale, R., & Bradley, M. M. (2008). Directed and motivated attention during processing of natural scenes. *Journal of Cognitive Neuroscience, 20(10),* 1753-1761.

Ferrari, V., De Cesarei, A., Mastria, S., Lugli, L., Baroni, G., Nicoletti, R., & Codispoti, M. (2016). Novelty and emotion: Pupillary and cortical responses during viewing of natural scenes. *Biological Psychology, 113,* 75-82.

Field, A. (2013). *Discovering statistics using SPSS statistics* (3rd ed.). Sage.

Flaisch, T., Junghöfer, M., Bradley, M. M., Schupp, H. T., & Lang, P. J. (2008a). Rapid picture processing: affective primes and targets. *Psychophysiology, 45(1),* 1-10.

Flaisch, T., Stockburger, J., & Schupp, H. T. (2008b). Affective prime and target picture processing: an ERP analysis of early and late interference effects. *Brain Topography, 20(4),* 183-191.

Folstein, J. R. & Van Petten, C. (2008). Influence of cognitive control and mismatch on the N2 component of the ERP: A review. *Psychophysiology, 45,* 152–170.

Foti, D., Hajcak, G., & Dien, J. (2009). Differentiating neural responses to emotional pictures: evidence from temporal-spatial PCA. *Psychophysiology, 46(3),* 521-530.

Franken, I. H., Muris, P., Nijs, I., & van Strien, J. W. (2008). Processing of pleasant information can be as fast and strong as unpleasant information: implications for the negativity bias. *Netherlands Journal of Psychology, 64(4),* 168-176.

Fredrikson, M., Wik, G., Greitz, T., Eriksson, L., Stone-Elander, S., Ericson, K., & Sedvall, G. (1993). Regional cerebral blood flow during experimental phobic fear. *Psychophysiology, 30,* 126–130.

Gable, P. A., Adams, D. L., & Hajcak, G. (2015). Transient tasks and enduring emotions: the impacts of affective content, task relevance, and picture duration on the sustained late positive potential. *Cognitive, Affective, & Behavioral Neuroscience, 15(1),* 45-54.

Gilboa-Schechtman, E., Foa, E. B., & Amir, N. (1999). Attentional biases for facial expressions in social phobia: The face-in-the-crowd paradigm. *Cognition & Emotion, 13(3),* 305-318.

Gómez, C. M., Delinte, A., Vaquero, E., Cardoso, M. J., Vazquez, M., Crommelinck, M., & Roucoux, A. (2001). Current source density analysis of CNV during temporal gap paradigm. *Brain Topography, 13(3),* 149-159.

Hajcak, G., Dunning, J. P., & Foti, D. (2007). Neural response to emotional pictures is unaffected by concurrent task difficulty: an event-related potential study. *Behavioral Neuroscience, 121(6),* 1156.

Hajcak, G., Dunning, J. P., & Foti, D. (2009). Motivated and controlled attention to emotion: time-course of the late positive potential. *Clinical Neurophysiology, 120(3),* 505-510.

Hajcak, G., MacNamara, A., & Olvet, D. M. (2010). Event-related potentials, emotion, and emotion regulation: an integrative review. *Developmental Neuropsychology, 35(2),* 129-155.

Hajcak, G., Moser, J. S., & Simons, R. F. (2006a). Attending to affect: appraisal strategies modulate the electrocortical response to arousing pictures. *Emotion, 6(3),* 517.

Hajcak, G., & Nieuwenhuis, S. (2006b). Reappraisal modulates the electrocortical response to unpleasant pictures. *Cognitive, Affective, & Behavioral Neuroscience, 6(4),* 291-297.

Hajcak, G., & Olvet, D. M. (2008). The persistence of attention to emotion: brain potentials during and after picture presentation. *Emotion, 8(2),* 250.

Hajcak, G., Weinberg, A., MacNamara. A., & Foti, D. (2012). *ERPs and the Study of Emotion.* In E. S. Kappenman & S. J. Luck (Eds.). Oxford Handbook of Event-Related Potential Components. Oxford University Press.

Herbert, C., Sfärlea, A., & Blumenthal, T. (2013). Your emotion or mine: labeling feelings alters emotional face perception — an ERP study on automatic and intentional affect labeling. *Frontiers in Human Neuroscience, 7,* 378.

Herring, D. R., Taylor, J. H., White, K. R., & Crites Jr, S. L. (2011). Electrophysiological responses to evaluative priming: the LPP is sensitive to incongruity. *Emotion, 11(4),* 794.

Hickey, C., McDonald, J. J., & Theeuwes, J. (2006). Electrophysiological evidence of the capture of visual attention*. Journal of Cognitive Neuroscience, 18,* 604-613.

Hietanen, J. K., & Astikainen, P. (2013). N170 response to facial expressions is modulated by the affective congruency between the emotional expression and preceding affective picture. *Biological Psychology, 92(2),* 114-124.

Hillyard, S. A., & Anllo-Vento, L. (1998a). Event-related brain potentials in the study of visual selective attention. *Proceedings of the National Academy of Sciences, 95(3),* 781-787.

Hillyard, S. A., Vogel, E. K., & Luck, S. J. (1998b). Sensory gain control (amplification) as a mechanism of selective attention: electrophysiological and neuroimaging evidence. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 353(1373),* 1257-1270.

Hirai, M., Watanabe, S., Honda, Y., Miki, K., & Kakigi, R. (2008). Emotional object and scene stimuli modulate subsequent face processing: An event-related potential study. *Brain Research Bulletin, 77(5),* 264-273.

Hodsoll, S., Viding, E., & Lavie, N. (2011). Attentional capture by irrelevant emotional distractor faces. *Emotion, 11(2),* 346.

Holmes, A., Kiss, M., & Eimer, M. (2006). Attention modulates the processing of emotional expression triggered by foveal faces. *Neuroscience Letters, 394(1),* 48-52.

Huang, Y. X., & Luo, Y. J. (2007). Attention shortage resistance of negative stimuli in an implicit emotional task. *Neuroscience Letters, 412(2),* 134-138.

IBM SPSS, Inc. (2010). *IBM SPSS Statistics 19.* IBM SPSS Inc., Chicago, ll.

Itier, R. J., & Taylor, M. J. (2004a). N170 or N1? Spatiotemporal differences between object and face processing using ERPs. *Cerebral Cortex, 14(2),* 132-142.

Itier, R. J., & Taylor, M. J. (2004b). Source analysis of the N170 to faces and objects. *Neuroreport, 15(8),* 1261-1265.

Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: the negativity bias in evaluative categorizations. *Journal of Personality & Social Psychology, 75(4),* 887.

Jiang, Y., Shannon, R. W., Vizueta, N., Bernat, E. M., Patrick, C. J., & He, S. (2009). Dynamics of processing invisible faces in the brain: automatic neural encoding of facial expression information. *Neuroimage, 44(3),* 1171-1177.

Johnston, V. S., & Wang, X. T. (1991). The relationship between menstrual phase and the P3 component of ERPs. *Psychophysiology, 28(4),* 400-409.

Jung, T. P., Makeig, S., Humphries, C., Lee, T. W., McKeown, M. J., Iragui, V., & Sejnowski, T. J. (2000). Removing electroencephalographic artifacts by blind source separation. *Psychophysiology, 37(2),* 163-178.

Junghöfer, M., Bradley, M. M., Elbert, T. R., & Lang, P. J. (2001). Fleeting images: a new look at early emotion discrimination. *Psychophysiology, 38(2),* 175-178.

Junhong, H., Renlai, Z., & Senqi, H. (2013). Effects on automatic attention due to exposure to pictures of emotional faces while performing Chinese word judgment tasks. *PloS One, 8(10),* e75386.

Kawasaki, H., Adolphs, R., Kaufman, O., Damasio, H., Damasio, A. R., Granner, M., Bakken, H., Hori, T., & Howard, M. A. (2001). Single-neuron responses to emotional visual stimuli recorded in human ventral prefrontal cortex. *Nature Neuroscience, 4(1),* 15-16.

Keil, A., Bradley, M. M., Hauk, O., Rockstroh, B., Elbert, T., & Lang, P. J. (2002). Large-scale neural correlates of affective picture processing. *Psychophysiology, 39(5),* 641-649.

Keil, A., Moratti, S., Sabatinelli, D., Bradley, M. M., & Lang, P. J. (2005). Additive effects of emotional content and spatial selective attention on electrocortical facilitation. *Cerebral Cortex, 15(8),* 1187-1197.

Keil, A., Müller, M. M., Gruber, T., Wienbruch, C., Stolarova, M., & Elbert, T. (2001). Effects of emotional arousal in the cerebral hemispheres: a study of oscillatory brain activity and event-related potentials. *Clinical Neurophysiology, 112(11),* 2057-2068.

Kenemans, J. L., Verbaten, M. N., Melis, C. J., & Slangen, J. L. (1992). Visual stimulus change and the orienting reaction: event-related potential evidence for a two-stage process. *Biological Psychology, 33(2-3),* 97-114.

Kenemans, J. L., Verbaten, M. N., Roelofs, J. W., & Slangen, J. L. (1989). "Initial-" and "change-orienting reactions": an analysis based on visual single-trial event-related potentials. *Biological Psychology, 28(3),* 199-226.

Kessel, D., Tapia, M., Hoyos, S., Capilla, A., & Carretié, L. (in preparation). The interaction effect of emotion and stimulus duration on event-related potentials.

Kincade, J. M., Abrams, R. A., Astafiev, S. V., Shulman, G. L., & Corbetta, M. (2005). An event-related functional magnetic resonance imaging study of voluntary and stimulus-driven orienting of attention. *The Journal of Neuroscience, 25(18),* 4593-4604.

Kleiner, M., Brainard, D., & Pelli, D. (2007). What's new in Psychtoolbox-3? *Perception, 36,* ECVP Abstract Supplement.

Kosslyn, S. M., Shin, L. M., Thompson, W. L., McNally, R. J., Rauch, S. L., Pitman, R. K., & Alpert, N. M. (1996). Neural effects of visualizing and perceiving aversive stimuli: a PET investigation. *Neuroreport, 7,* 1569–1576.

Kuniecki, M., Pilarczyk, J., & Wichary, S. (2015). The color red attracts attention in an emotional context. An ERP study. *Frontiers in Human Neuroscience*, 9.

Lane, R. D., Reiman, E. M., Bradley, M. M., Lang, P. J., Ahern, G. L., Davidson, R. J., & Schwartz, G. E. (1997). Neuroanatomical correlates of pleasant and unpleasant emotion. *Neuropsychologia, 35,* 1437–1444.

Lang, P. J., & Bradley, M. M. (2010). Emotion and the motivational brain. *Biological Psychology, 84(3),* 437-450.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999*). International affective picture system (IAPS): Instruction manual and affective ratings.* Gainsville, Florida: The Center for Research in Psychophysiology, University of Florida.

Lang, P. J., Bradley, M. M., Fitzsimmons, J. R., Cuthbert, B. N., Scott, J. D., Moulder, B., & Nangia, V. (1998). Emotional arousal and activation of the visual cortex: an fMRI analysis. *Psychophysiology, 35,* 199–210.

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology, 30(3),* 261-273.

Lavie, N. (2005). Distracted and confused? Selective attention under load. *Trends in Cognitive Sciences, 9,* 75-82.

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience, 23,* 155–184.

Lichtenstein-Vidne, L., Henik, A., & Safadi, Z. (2012). Task relevance modulates processing of distracting emotional stimuli. *Cognition & Emotion, 26(1),* 42-52.

Lifshitz, K. (1966). The averaged evoked cortical response to complex visual stimuli. *Psychophysiology, 3(1),* 55-68.

López-Martín, S., Albert, J., Fernández-Jaén, A., & Carretié, L. (2013). Emotional distraction in boys with ADHD: neural and behavioral correlates. *Brain & Cognition, 83(1),* 10-20.

Luck, S. J., & Hillyard, S. A. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiology, 31(3),* 291-308.

Luck, S. J., Hillyard, S. A., Mouloua, M., Woldorff, M. G., Clark, V. P., & Hawkins, H. L. (1994). Effects of spatial cuing on luminance detectability: psychophysical and electrophysiological evidence for early selection. *Journal of Experimental Psychology: Human Perception and Performance, 20(4),* 887.

Ma, J., Liu, C., & Chen, X. (2016). Emotional modulation of conflict processing in the affective domain: evidence from event-related potentials and event-related spectral perturbation analysis. *Scientific Reports, 6.*

MacNamara, A., & Hajcak, G. (2009). Anxiety and spatial attention moderate the electrocortical response to aversive pictures. *Neuropsychologia, 47,* 2975-2980.

MacNamara, A., & Hajcak, G. (2010). Distinct electrocortical and behavioral evidence for increased attention to threat in generalized anxiety disorder. *Depression & Anxiety, 27,* 234-243.

MacNamara, A., Kappenman, E. S., Black, S. R., Bress, J. N., & Hajcak, G. (2012). *Integrating behavioral and electrocortical measures of attentional bias toward threat.* In K. Caplovitz-Barrett, N. A. Fox, G. A. Morgan, D. J. Fidler, and L. A. Daunhauer (Eds.), Handbook of self-regulatory processes in development: New directions and international perspectives (pp. 215-242). New York, NY: Psychology Press.

Mangun, G. R., & Hillyard, S. A. (1990). Allocation of visual attention to spatial locations: Tradeoff functions for event-related brain potentials and detection performance. *Perception & Psychophysics, 47(6),* 532-550.

Mangun, G. R., Hopfinger, J. B., Kussmaul, C. L., Fletcher, E. M., & Heinze, H. J. (1997). Covariations in ERP and PET measures of spatial selective attention in human extrastriate visual cortex. *Human Brain Mapping, 5(4),* 273-279.

Marchewka, A., Żurawski, Ł., Jednoróg, K., & Grabowska, A. (2014). The Nencki Affective Picture System (NAPS): Introduction to a novel, standardized, wide-range, high-quality, realistic picture database. *Behavior Research Methods, 46(2),* 596-610.

Melcher, T., Born, C., & Gruber, O. (2011). How negative affect influences neural control processes underlying the resolution of cognitive interference: an event-related fMRI study. *Neuroscience Research, 70(4),* 415-427.

Mini, A., Palomba, D., Angrilli, A., & Bravi, S. (1996). Emotional information processing and visual evoked brain potentials. *Perceptual & Motor Skills, 83(1),* 143-152.

Moore, T., & Armstrong, K. M. (2003). Selective gating of visual signals by microstimulation of frontal cortex. *Nature, 421(6921),* 370-373.

Morel, S., Ponz, A., Mercier, M., Vuilleumier, P., & George, N. (2009). EEG-MEG evidence for early differential repetition effects for fearful, happy and neutral faces. *Brain Research, 1254,* 84-98.

Moriya, H., & Nittono, H. (2011). Effect of mood states on the breadth of spatial attentional focus: an event-related potential study. *Neuropsychologia, 49(5),* 1162-1170.

Mourão-Miranda, J., Volchan, E., Moll, J., de Oliveira-Souza, R., Oliveira, L., Bramati, I., Gattass, R., & Pessoa, L. (2003). Contributions of stimulus valence and arousal to visual activation during emotional perception. *Neuroimage, 20,* 1955–1963.

Mühlberger, A., Wieser, M. J., Herrmann, M. J., Weyers, P., Tröger, C., & Pauli, P. (2009). Early cortical processing of natural and artificial emotional faces differs between lower and higher socially anxious persons. *Journal of Neural Transmission, 116(6),* 735-746.

Müller, M. M., Andersen, S. K., & Keil, A. (2008). Time course of competition for visual processing resources between emotional pictures and foreground task. *Cerebral Cortex, 18(8),* 1892-1899.

Müller, M. M., Andersen, S. K., & Attar, C. H. (2011). Attentional bias to briefly presented emotional distractors follows a slow time course in visual cortex. *Journal of Neuroscience, 31(44),* 15914-15918.

Nigbur, R., Schneider, J., Sommer, W., Dimigen, O., & Stürmer, B. (2015). Ad-hoc and context-dependent adjustments of selective attention in conflict control: An ERP study with visual probes. *Neuroimage, 107*, 76-84.

Nordström, H., & Wiens, S. (2012). Emotional event-related potentials are larger to figures than scenes but are similarly reduced by inattention. *BMC Neuroscience, 13(1),* 49.

Northoff, G., Richter, A., Gessner, M., Schlagenhauf, F., Fell, J., Baumgart, F., Kaulisch, T., Kötter, R., Stephan, K.E., Leschinger, A., Hagner, T., Bargel, B., Witzel, T., Hinrichs, H., Bogerts, B., Scheich, H., & Heinze, H. J. (2000). Functional dissociation between medial and lateral prefrontal cortical spatiotemporal activation in negative and positive emotions: a combined fMRI/MEG study. *Cerebral Cortex, 10(1),* 93-107.

Ochsner, K. N., Ray, R. R., Hughes, B., McRae, K., Cooper, J. C., Weber, J., Gabrieli, J. D. E., & Gross, J. J. (2009). Bottom-up and top-down processes in emotion generation common and distinct neural mechanisms. *Psychological Science, 20(11),* 1322-1331.

O'Hare, A. J., Atchley, R. A., & Young, K. M. (2016). Valence and arousal influence the late positive potential during central and lateralized presentation of images. *Laterality: Asymmetries of Body, Brain and Cognition, 1-19*.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology: General, 130(3),* 466.

Öhman, A., Hamm, A., & Hugdahl, K. (2000). *Cognition and the autonomic nervous system: orienting, anticipation, and conditioning.* In: J. T. Cacioppo, L. G. Tassinary, G. G. Bernston (Eds.). Handbook of Psychophysiology (2nd ed.). Cambridge University Press, Cambridge, pp. 533–575.

Olatunji, B. O., Armstrong, T., & Ciesielski, B. G. (2015). Differential effects of emotional expressions and scenes on visual search. *Motivation and Emotion*, 1-13.

Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: an integrative review of ERP findings. *Biological Psychology, 77(3),* 247-265.

Olofsson, J. K., & Polich, J. (2007). Affective visual event-related potentials: arousal, repetition, and time-on-task. *Biological Psychology, 75(1),* 101-108.

Osgood, C. E., Suci, G. J., & Tannenbaum, P. H. (1957). *The Measurement of Meaning.* Urbana: University of Illinois Press.

Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J. M. (2011). FieldTrip: open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. *Computational Intelligence & Neuroscience, 2011*, Article ID 156869.

Palomba, D., Angrilli, A., & Mini, A. (1997). Visual evoked potentials, heart rate responses and memory to emotional pictorial stimuli. *International Journal of Psychophysiology, 27(1),* 55-67.

Pastor, M. C., Bradley, M. M., Löw, A., Versace, F., Moltó, J., & Lang, P. J. (2008). Affective picture perception: emotion, context, and the late positive potential. *Brain Research, 1189,* 145-151.

Pazo-Álvarez, P., Cadaveira, F., & Amenedo, E. (2003). MMN in the visual modality: a review. *Biological Psychology, 63(3),* 199-236.

Petersen, S. E., Robinson, D. L., and Morris, J. D. (1987). Contributions of the pulvinar to visual spatial attention. *Neuropsychologia, 25,* 97–105.

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Reviews of Neuroscience, 13,* 25-42.

Posner, M. I., Rueda, M. R., & Kanske, P. (2007). *Probing the mechanisms of attention.* In J. T. Cacioppo, J. G. Tassinary, & G. G. Berntson (Eds.). The Handbook of Psychophysiology (3rd ed., pp. 410–432). Cambridge: Cambridge University Press.

Pourtois, G., Delplanque, S., Michel, C., & Vuilleumier, P. (2008). Beyond conventional event-related brain potential (ERP): exploring the time-course of visual emotion processing using topographic and principal component analyses. *Brain Topography, 20(4),* 265-277.

Pourtois, G., Grandjean, D., Sander, D., & Vuilleumier, P. (2004). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral Cortex, 14(6),* 619-633.

Pourtois, G., Schettino, A., & Vuilleumier, P. (2013). Brain mechanisms for emotional influences on perception and attention: what is magic and what is not. *Biological Psychology, 92(3),* 492-512.

Pourtois, G., Spinelli, L., Seeck, M., & Vuilleumier, P. (2010). Temporal precedence of emotion over attention modulations in the lateral amygdala: Intracranial ERP evidence from a patient with temporal lobe epilepsy. *Cognitive, Affective, & Behavioral Neuroscience, 10(1),* 83-93.

Pourtois, G., Thut, G., de Peralta, R. G., Michel, C., & Vuilleumier, P. (2005). Two electrophysiological stages of spatial orienting towards fearful faces: early temporo-parietal activation preceding gain control in extrastriate visual cortex. *Neuroimage, 26(1),* 149-163.

Radilová, J. (1982). The late positive component of visual evoked response sensitive to emotional factors. *Activitas Nervosa Superior, Supplement 3,* 334-337.

Radilová, J., Figar, S., & Radil, T. (1983). Sexual arousal and visual perception. *Activitas Nervosa Superior, 25(3),* 168–170.

Rauss, K., Schwartz, S., & Pourtois, G. (2011). Top-down effects on early visual processing in humans: A predictive coding framework. *Neuroscience & Biobehavioral Reviews, 35(5),* 1237-1253.

Rellecke, J., Sommer, W., & Schacht, A. (2012). Does processing of emotional facial expressions depend on intention? Time-resolved evidence from event-related brain potentials. *Biological Psychology, 90(1),* 23-32.

Righart, R., & De Gelder, B. (2006). Context influences early perceptual analysis of faces — an electrophysiological study. *Cerebral Cortex, 16(9),* 1249-1257.

Righart, R., & De Gelder, B. (2008a). Rapid influence of emotional scenes on encoding of facial expressions: an ERP study. *Social, Cognitive, & Affective Neuroscience, 3(3),* 270-278.

Righart, R., & De Gelder, B. (2008b). Recognition of facial expressions is influenced by emotional scene gist. *Cognitive, Affective, & Behavioral Neuroscience, 8(3),* 264-272.

Rigoulot, S., D'Hondt, F., Defoort-Dhellemmes, S., Despretz, P., Honoré, J., & Sequeira, H. (2011). Fearful faces impact in peripheral vision: behavioral and neural evidence. *Neuropsychologia, 49(7),* 2013-2021.

Rodman, H. R., & Consuelos, M. J. (1994). Cortical projections to anterior inferior temporal cortex in infant macaque monkeys. *Visual Neuroscience, 11,* 119–133.

Rokke, P. D., & Lystad, C. M. (2015). Mood-specific effects in the allocation of attention across time. *Cognition and Emotion, 29(1),* 27-50.

Rossi, V., & Pourtois, G. (2012). State-dependent attention modulation of human primary visual cortex: A high density ERP study. *Neuroimage, 60(4),* 2365-2378.

Rossi, V., & Pourtois, G. (in press). Someone's lurking in the dark: The role of state anxiety on attention deployment to threat-related stimuli. *Biological Psychology.*

Rossignol, M., Campanella, S., Maurage, P., Heeren, A., Falbo, L., & Philippot, P. (2012). Enhanced perceptual responses during visual processing of facial

stimuli in young socially anxious individuals. *Neuroscience Letters, 526(1),* 68-73.

Rothermund, K., Wentura, D., & Bak, P. M. (2001). Automatic attention to stimuli signalling chances and dangers: Moderating effects of positive and negative goal and action contexts. *Cognition & Emotion, 15(2),* 231-248.

Rousselet, G. A., Macé, M. J., & Fabre-Thorpe, M. (2004). Spatiotemporal analyses of the N170 for human faces, animal faces and objects in natural scenes. *Neuroreport, 15(17),* 2607-2611.

Rozenkrants, B., & Polich, J. (2008). Affective ERP processing in a visual oddball task: arousal, valence, and gender. *Clinical Neurophysiology, 119(10),* 2260-2265.

Ruff, C.C., Blankenburg, F., Bjoertomt, O., Bestmann, S., Freeman, E., Haynes, J. D., Rees, G., Josephs, O., Deichmann, R., & Driver, J. (2006). Concurrent TMS-fMRI and psychophysics reveal frontal influences on human retinotopic visual cortex. *Current Biology, 16,* 1479–1488.

Ruff, C.C., Bestmann, S., Blankenburg, F., Bjoertomt, O., Josephs, O., Weiskopf, N., Deichmann, R., & Driver, J. (2007). Distinct causal influences of parietal versus frontal areas on human visual cortex: evidence from concurrent TMS fMRI. *Cerebral Cortex, 18,* 817–827.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*(6), 1161.

Sabatinelli, D., Fortune, E. E., Li, Q., Siddiqui, A., Krafft, C., Oliver, W. T., Beck, S., & Jeffries, J. (2011). Emotional perception: meta-analyses of face and natural scene processing. *Neuroimage, 54(3),* 2524-2533.

Sabatinelli, D., Keil, A., Frank, D. W., & Lang, P. J. (2013). Emotional perception: correspondence of early and late event-related potentials with cortical and subcortical functional MRI. *Biological Psychology, 92(3),* 513-519.

Sabatinelli, D., Lang, P. J., Keil, A., & Bradley, M. M. (2007). Emotional perception: correlation of functional MRI and event-related potentials. *Cerebral Cortex, 17(5),* 1085-1091.

Sadeh, B., Podlipsky, I., Zhdanov, A., & Yovel, G. (2010). Event-related potential and functional MRI measures of face-selectivity are highly correlated: A simultaneous ERP-fMRI investigation. *Human Brain Mapping, 31(10),* 1490-1501.

Schönfelder, S., Kanske, P., Heissler, J., & Wessa, M. (2014). Time course of emotion-related responding during distraction and reappraisal. *Social, Cognitive, & Affective Neuroscience, 9(9),* 1310-1319.

Schönwald, L. I., & Müller, M. M. (2014). Slow biasing of processing resources in early visual cortex is preceded by emotional cue extraction in emotion–attention competition. *Human Brain Mapping, 35(4),* 1477-1490.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T., & Lang, P. J. (2000). Affective picture processing: the late positive potential is modulated by motivational relevance. *Psychophysiology, 37(2),* 257-261.

Schupp, H., Cuthbert, B., Bradley, M., Hillman, C., Hamm, A., & Lang, P. (2004b). Brain processes in emotional perception: Motivated attention. *Cognition & Emotion, 18(5),* 593-611.

Schupp, H. T., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006a). Emotion and attention: event-related brain potential studies. *Progress in Brain Research, 156,* 31-51.

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2003a). Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. *Neuroreport, 14(8),* 1107-1110.

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2004a). The selective processing of briefly presented affective pictures: an ERP analysis. *Psychophysiology, 41(3),* 441-449.

Schupp, H. T., Markus, J., Weike, A. I., & Hamm, A. O. (2003b). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science, 14(1),* 7-13.

Schupp, H. T., Öhman, A., Junghöfer, M., Weike, A. I., Stockburger, J., & Hamm, A. O. (2004). The facilitated processing of threatening faces: an ERP analysis. *Emotion, 4(2),* 189.

Schupp, H. T., Schmälzle, R., Flaisch, T., Weike, A. I., & Hamm, A. O. (2013). Reprint of "Affective picture processing as a function of preceding picture valence: An ERP analysis". *Biological Psychology, 92(3),* 520-525.

Schupp, H. T., Stockburger, J., Bublatzky, F., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2007a). Explicit attention interferes with selective emotion processing in human extrastriate cortex. *BMC Neuroscience, 8(1),* 1.

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2007b). Selective visual attention to emotion. *The Journal of Neuroscience, 27(5),* 1082-1089.

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2006b). Stimulus novelty and emotion perception: the near absence of habituation in the visual cortex. *Neuroreport, 17(4),* 365-369.

Schupp, H. T., Stockburger, J., Schmälzle, R., Bublatzky, F., Weike, A. I., & Hamm, A. O. (2008). Visual noise effects on emotion perception: brain potentials and stimulus identification. *Neuroreport, 19(2),* 167-171.

Schwager, S., & Rothermund, K. (2013). Counter-regulation triggered by emotions: Positive/negative affective states elicit opposite valence biases in affective processing. *Cognition & Emotion, 27(5),* 839-855.

Shipp, S. (2004). The brain circuitry of attention. *Trends in Cognitive Science, 8,* 223–230.

Shulman, G. L., Pope, D. L., Astafiev, S. V., McAvoy, M. P., Snyder, A. Z., & Corbetta, M. (2010). Right hemisphere dominance during spatial selective attention and target detection occurs outside the dorsal frontoparietal network. *The Journal of Neuroscience, 30(10),* 3640-3651.

Smith, M. L. (2012). Rapid processing of emotional expressions without conscious awareness. *Cerebral Cortex, 22(8),* 1748-1760.

Smith, C. A., & Ellsworth, P. C. (1985). Patterns of cognitive appraisal in emotion. *Journal of Personality and Social Psychology, 48(4),* 813.

Smith, N. K., Cacioppo, J. T., Larsen, J. T., & Chartrand, T. L. (2003). May I have your attention, please: Electrocortical responses to positive and negative stimuli. *Neuropsychologia, 41(2),* 171-183.

Smith, N. K., Larsen, J. T., Chartrand, T. L., Cacioppo, J. T., Katafiasz, H. A., & Moran, K. E. (2006). Being bad isn't always good: Affective context moderates the attention bias toward negative information. *Journal of Personality & Social Psychology, 90(2),* 210.

Spreckelmeyer, K. N., Kutas, M., Urbach, T. P., Altenmüller, E., & Münte, T. F. (2006). Combined perception of emotion in pictures and musical sounds. *Brain Research, 1070(1),* 160-170.

Summerfield, C., & Egner, T. (2009). Expectation (and attention) in visual cognition. *Trends in Cognitive Sciences, 13(9),* 403-409.

Syrjänen, E., & Wiens, S. (2013). Gender moderates valence effects on the late positive potential to emotional distracters. *Neuroscience Letters, 551,* 89-93.

Tabachnick, B. G. & Fidell, L. S. (2001). *Using multivariate statistics* (4th ed.). Boston: Allyn & Bacon.

Thom, N., Knight, J., Dishman, R., Sabatinelli, D., Johnson, D. C., & Clementz, B. (2014). Emotional scenes elicit more pronounced self-reported emotional experience and greater EPN and LPP modulation when compared to emotional faces. *Cognitive, Affective, & Behavioral Neuroscience, 14(2),* 849-860.

Tiferet-Dweck, C., Hensel, M., Kirschbaum, C., Tzelgov, J., Friedman, A., & Salti, M. (2016). Acute Stress and Perceptual Load Consume the Same Attentional Resources: A Behavioral-ERP Study. *PLoS One, 11(5),* e0154622.

Tortosa, M. I., Lupiáñez, J., & Ruz, M. (2013). Race, emotion and trust: An ERP study. *Brain Research, 1494,* 44-55.

Van Dessel, P. & Vogt, J. (2012). When does hearing laughter draw attention to happy faces? Task relevance determines the influence of a crossmodal affective context on emotional attention. *Frontiers in Human Neuroscience, 6,* 294.

Van Hooff, J. C., Devue, C., Vieweg, P. E., & Theeuwes, J. (2013). Disgust-and not fear-evoking images hold our attention. *Acta Psychologica, 143(1),* 1-6.

Vanlessen, N., Rossi, V., De Raedt, R., & Pourtois, G. (2013). Positive emotion broadens attention focus through decreased position-specific spatial encoding in early visual cortex: Evidence from ERPs. *Cognitive, Affective, & Behavioral Neuroscience, 13(1),* 60-79.

Vanlessen, N., Rossi, V., De Raedt, R., & Pourtois, G. (2014). Feeling happy enhances early spatial encoding of peripheral information automatically: electrophysiological time-course and neural sources. *Cognitive, Affective, & Behavioral Neuroscience, 14(3),* 951-969.

Vogel, E. K., & Luck, S. J. (2000). The visual N1 component as an index of a discrimination process. *Psychophysiology, 37(02),* 190-203.

Vromen, J. M., Lipp, O. V., Remington, R. W., & Becker, S. I. (2016). Threat captures attention, but not automatically: Top-down goals modulate attentional orienting to threat distractors. *Attention, Perception, & Psychophysics,* 1-14.

Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9(12),* 585-594.

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2003). Distinct spatial frequency sensitivities for processing faces and emotional expressions. *Nature Neuroscience, 6(6),* 624-631.

Vuilleumier, P., & Huang, Y. M. (2009). Emotional attention uncovering the mechanisms of affective biases in perception. *Current Directions in Psychological Science, 18(3),* 148-152.

Wadlinger, H. A., & Isaacowitz, D. M. (2006). Positive mood broadens visual attention to positive stimuli. *Motivation & Emotion, 30(1),* 87-99.

Weinberg, A., & Hajcak, G. (2010). Beyond good and evil: the time-course of neural activity elicited by specific picture content. *Emotion, 10(6),* 767.

Weinberg, A., Hilgard, J., Bartholow, B. D., & Hajcak, G. (2012). Emotional targets: evaluative categorization as a function of context and content. *International Journal of Psychophysiology, 84(2),* 149-154.

Wentura, D., Voss, A., & Rothermund, K. (2009). Playing TETRIS for science counter-regulatory affective processing in a motivationally "hot" context. *Acta Psychologica, 131(3),* 171-177.

West, G. L., Anderson, A. A., Ferber, S., & Pratt, J. (2011). Electrophysiological evidence for biased competition in V1 for fear expressions. *Journal of Cognitive Neuroscience, 23(11),* 3410-3418.

Wiens, S., Sand, A., Norberg, J., & Andersson, P. (2011). Emotional event-related potentials are reduced if negative pictures presented at fixation are unattended. *Neuroscience Letters, 495(3),* 178-182.

Wiens, S., & Syrjänen, E. (2013). Directed attention reduces processing of emotional distracters irrespective of valence and arousal level. *Biological Psychology, 94(1),* 44-54.

Wild-Wall, N., Dimigen, O., & Sommer, W. (2008). Interaction of facial expressions and familiarity: ERP evidence*. Biological Psychology, 77(2),* 138-149.

Williams, L. M., Palmer, D., Liddell, B. J., Song, L., & Gordon, E. (2006). The 'when'and 'where' of perceiving signals of threat versus non-threat. *Neuroimage, 31(1),* 458-467.

Wood, S., & Kisley, M. A. (2006). The negativity bias is eliminated in older adults: age-related reduction in event-related brain potentials associated with evaluative categorization. *Psychology & Aging, 21(4),* 815.

Wronka, E., & Walentowska, W. (2011). Attention modulates emotional expression processing. *Psychophysiology, 48(8),* 1047-1056.

Yantis, S. (1993). Stimulus-driven attentional capture. *Current Directions in Psychological Science, 2(5),* 156-161.

Yuan, J., Chen, J., Yang, J., Ju, E., Norman, G. J., & Ding, N. (2014). Negative mood state enhances the susceptibility to unpleasant events: neural correlates from a music-primed emotion classification task. *PLoS One, 9(2),* e89844.

Yuan, L., Zhou, R., & Hu, S. (2014). Cognitive reappraisal of facial expressions: Electrophysiological evidence of social anxiety. *Neuroscience Letters,* 577, 45-50.

Zar, J. (1996). *Biostatistical analysis.* Englewood Cliffs, NJ: Prentice-Hall.

Zhang, D., Wang, L., Luo, Y., & Luo, Y. (2012). Individual differences in detecting rapidly presented fearful faces. *PloS One, 7(11),* e49517.

Zhao, L., & Li, J. (2006). Visual mismatch negativity elicited by facial expressions under non-attentional condition. *Neuroscience Letters, 410(2),* 126-131.

Zlomke, K., & Davis III, T. E. (2008). One-session treatment of specific phobias: A detailed description and review of treatment efficacy. *Behavior Therapy, 39(3),* 207-223.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